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VOL. XIX



# ACTA ORTHOPAEDICA SCANDINAVICA

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## EDITORIAL NOTE

A paper by Olov Lindahl entitled "On the Chlorine Content of Human Muscle and Skeletal Tissue. With Special Reference to the Degeneration of Cartilage" was published in Fasciculi 3 and 4, vol. XVIII of this journal. Before accepting it for publication in the Acta Orthopaedica it was sent for scrutiny by the chemists. After its publication the chemical method upon which the work was based was re-examined and shown to involve an error which had not been detected by the author. The editorial board record their regret, and, with Prof. Jorpes' permission, append a short account of the result of the control investigations.

*Sten Friberg.*

## "BOUND" CHLORINE IN CASEIN AND IN TISSUE PROTEINS

BY

VICTOR MUTT, Assistant.

*Lindahl* recently analysed casein, and found that it contained about one per cent chlorine in bound form. In the analytical method used by him the casein was treated with a boiling mixture of chromic and sulphuric acids, and the gases evolved were passed through a known quantity of silver nitrate containing  $\text{As}_2\text{O}_3$ . The consumption of silver nitrate, assumed to be due to the chlorine in the casein, was determined by the Volhard method. As the presence of chlorine in casein does not agree with the generally accepted opinion on the composition of this protein it seemed necessary to check *Lindahl's* results. At the suggestion of Professor *E. Jorpes* I undertook to control the analytical procedure. Dr. *Ragnar Berg* who performed the analyses for *Lindahl* kindly demonstrated his technique in our laboratory, thereby greatly facilitating our work.

Casein, prepared by isoelectric precipitation with acetic acid, was analysed for chlorine by the Carius method. No trace of chlorine could be detected. When the analysis was performed with the technique used by *Lindahl*, a precipitate insoluble in nitric acid was actually formed, and the Volhard titration showed a consumption of silver nitrate corresponding to 0.25 per cent chlorine in the casein. It was, however, observed that the precipitate differed from silver chloride in that it did not darken when exposed to sunlight. When fused with

$\text{Na}_2\text{CO}_3$  no chloride was obtained in the alkaline filtrate whereas a similar quantity of silver chloride gave a quantitative precipitate with  $\text{AgNO}_3$  on acidification with  $\text{HNO}_3$ . Evidently the precipitate formed in the trap with silver nitrate was not silver chloride. Of the different silver salts that might be formed the formate, carbonate and acetate are readily soluble in dilute nitric acid. The oxalate darkens easily in sunlight. The silver cyanide, however, is practically insoluble in dilute and only slowly soluble in concentrated nitric acid; moreover, it does not darken when exposed to sunlight. Consequently, the precipitate was assumed to be silver cyanide. This assumption was confirmed by analyses of the sample. A qualitative test for the cyanide ion with ammonium polysulphide and ferric chloride was positive. On ignition of 31,265 mg the silver residue weighed 25,065 mg or 80.17 per cent. The calculated amount of silver in silver cyanide is 80.57 per cent. In another sample the ignition residue was dissolved in nitric acid precipitated with hydrochloric acid and the precipitate weighed. The silver content of the chloride corresponded to 80.2 per cent of the original sample.

Evidently this source of error in the chlorine determination escaped the attention of *Lindahl*. His conclusions about the protein-bound chlorine in the body are consequently erroneous.

PROCEEDINGS OF THE NORDISK ORTOPEDISK FORENING'S  
23rd MEETING IN ARHUS AND COPENHAGEN

23rd AND 24th OF SEPTEMBER 1948

In the chair: *P. G. K. Bentzon*, Århus.

1. *Aa. Randløv-Madsen*: Experimental investigations into the aetiology of Calve-Perthes' disease.
2. *A. Langenskiöld*: The growth mechanism of the epiphyseal cartilage in the light of experimental observation.
3. *F. Langenskiöld*: Coxa vara congenita on infantum with pseudarthrosis in the neck of the femur.
4. *L. Einarson*: On the internal structure of the motor cells of the anterior horns and its changes in poliomyelitis.  
- - Notes on the histochemical aspect of the changes of the spinal motor cells in anoxia, vitamin E deficiency and poliomyelitis.
5. Demonstration of Steeper's new mechanical hand.
6. *H. Kjerholm*: On treatment of fractures of the jaw, especially the fractures of the neck of the mandible.
7. *K. Rojel*: On the treatment of radial palsy by tendontransplantation.
8. *N. Silfverskiöld*: Demonstration of an abduction splint with pelvic support and splint for the digits.
9. *E. Thomasen*: Arthrogryposis multiplex.
10. *P. G. K. Bentzon & J. Agerholm-Christensen*: Lambirundi's operation for drop-foot.
11. *S. von Rosen*: On osteosynthesis in the treatment of pseudarthrosis of the femoral neck.
12. *H. Støren*: A contribution to the treatment of pseudarthrosis of the femoral neck.
13. *J. Agerholm-Christensen*: On Denis Browne's treatment of club-foot.
14. *Fr. Therkelsen & Kjeld Andersen*: Fractures of the carpal bones, with particular references to the scaphoid.
15. *Hans Novotny*: Conservative treatment of clavicular fractures.
16. *Ragnar Magnusson*: The scalenus anticus syndrome.
17. *Erik Moberg*: On the technique and possibilities of reconstructive hand surgery.

18. *J. Agerholm-Christensen*: A simple instrument for a modified Bankart's operation for recurrent dislocation of the shoulder.
19. *P. G. K. Bentzon*: Film from the international orthopaedic congress at Amsterdam september 1948.
20. *Ingeborg Lou*: A follow up examination of olecranon fractures.
21. *H. Starklint & J. Staun*: The effect of tetraethyl ammonium bromide on dysbasia arteriosclerotica.
22. *E. Henriksen*: Some cases of functional vascular disorders.
23. *E. Hasner*: On treatment of osteochondrosis of the spine by spinal fusion.
24. *H. Jensenius*: Fracture of the astragalus.

## EXPERIMENTAL INVESTIGATIONS INTO THE AETIOLOGY OF CALVÉ-PERTHES' DISEASE

BY

AA. RANDLOV-MADSEN

Through the years there appear regularly new theories about the aetiology of Calvé-Perthes' disease. In them can be detected a well-founded doubt about *Axhausen's* theory, which has otherwise been widely accepted.

Gradually all possible causes have been considered in the search for an explanation of *Calvé-Perthes'* disease and related conditions. The following review does not claim to be complete; it aims only to give an impression of the multiplicity of theories.

It has often been suggested that the basis of the condition must be either hereditary or constitutional. This idea is supported by the observations of *Aage Nielsen* and *Mollzen-Nielsen*.

*Ribbing* based his theory on the assumption of small abnormal bone nuclei having fragile and vulnerable connection with the surrounding tissue.

*Göcke* sought a purely physical explanation, assuming that the elasticity and resistance of the cancellous bone was reduced by small traumata.

*Block* gave a chemical explanation: a disturbance of water and salt metabolism.

The frequent occurrence of the condition in individuals of so-called "endocrine" character draws attention to the possibility of a hormonal disturbance.

*Fromme* considers that the condition resembles rickets.

Infection (e.g. syphilis) and toxic poisoning were early rejected as causes, since they were not supported by the histological findings.

The possibility of tumor formation—chondroma or giant cell tumor—has been considered (*Preiser* and *Fraenkel*).

Amongst investigators in recent years *Nagura* has been the most energetic champion of trauma as the main cause of the condition. He thought he found, in a specimen of osteochondritis of the elbow, slight solution of continuity with a resulting "demarcation process of the cartilage". Using young rabbits he submitted the femoral head to small traumata and produced mixed states of ossification which he compared with *Calvé-Perthes'* disease. He described these process in the following way:

- 1) First breakdown: the small primary lesion.
- 2) First repair: the formation of cartilage callus and ossification.
- 3) Second breakdown, which occurs when satisfactory conditions for regeneration are lacking; it consists of regressive changes determined by the mechanical factors.
- 4) Second repair.

*Calvé-Perthes'* disease should be the same as the second breakdown and the second repair. *Nagura* does not explain the predilection for a certain age and site, the familial incidence, etc.

Impaired and increased blood-supply have also been considered. *Legg*, who was one of the first to study the disease, in 1908, thought that the vessels at the junction between the femoral neck and epiphysis might be interrupted by injury.

*Axhausen* thought that the condition was based on a necrosis due to obstruction of the arteries with emboli, which were probably non-infective bacterial emboli. The theory was based on observations of necrosis of the whole or parts of the epiphysis. Certainly necrosis can be found. But if the histological studies of *Calvé-Perthes'* disease are examined one



finds that necrosis is by no means a predominating or constant characteristic; cases have even been described where there was no necrosis (*Motojima*). This theory fails to explain the most typical characters: familial incidence, preference for one sex, simultaneous appearance of changes in the head and acetabulum, etc.

*Ipsen* introduced arterial spasm into the discussion.

*Leriche* thinks that hyperaemia may explain the condition.

*Bentzon* recognised that it was a proliferative process—a kind of “pathological callus formation”—and this seems to me to be of great importance for the further study of the disease. The theory is that the process develops from a hyperaemia due to minor lesions of the very vulnerable nerve elements which play a part in the vasomotor regulation. Certainly, however, there must be local and general changes to start the process. *Bentzon* thought that he would find support for his views by experiments in which alcohol was injected round the vessels and nerves concerned, using young rabbits.

The theories already mentioned have hardly passed the stage of stating the problem and I have therefore tried by basing my investigations on *Bentzon*'s work, to carry further those studies which seemed to me to have most nearly reproduced *Calvé-Perthes*' disease.

In the first series of experiments 28 rabbits aged between 4 and 7 weeks were used. 0.25 ml. 80 % sterile alcohol was injected on the inferior side of the R. femoral neck at the place where the main artery to the head is usually found. The aim was to submit the vessels, and the nerves, to a 'traumatic' effect. Marked changes were found in 2 animals aged 4 weeks and slight changes in 4 between 4 and 5 weeks. Radiography showed slight flattening of the head, often with increased growth on the medial side of the neck, and valgus

position. The surface of the head showed slight condensation and waviness. In 2 animals there were definite microscopic changes similar to those found in the second series.

In the second series of experiments alcohol was injected into 26 young rabbits as in the first series, but the injections



*Fig. 1.*

were repeated 2 to 4 times at intervals of a few days. Here also a marked difference was found between the different age-groups: all except one of the 4-week-old rabbits showed marked changes, while the slightly older animals, 6-10 weeks, showed only slight changes, and 6 showed no changes at all.

Macroscopically there was flattening of the femoral head corresponding to the uppermost weightbearing part. The cartilaginous surface was irregularly waved with depressions

in it. The cartilage was yellowish, and seemed to be less transparent than on the sound side (fig. 1).

Radiography showed the following changes (fig. 2): flattening of the head with an irregular joint surface, often wavy, but sometimes roughened. The head itself was usually condensed, especially in the subchondral zone. In some pic-



*Fig. 2.*

tures there were small transparencies. The epiphyseal cartilage showed very marked changes: it was increased in breadth with a more irregular wavy formation and indefinite outlines. Usually the neck showed rather diffuse, rarely patchy, transparency. In many of the cases a valgus deformity of the neck had developed. On the inferior surface of the neck there was usually a reaction to the alcohol injection: sometimes flat, and sometimes bulbous proliferations or spur-shaped formations.

Microscopy showed marked changes in 20 animals: again the head showed an irregular and flattened outline. The joint

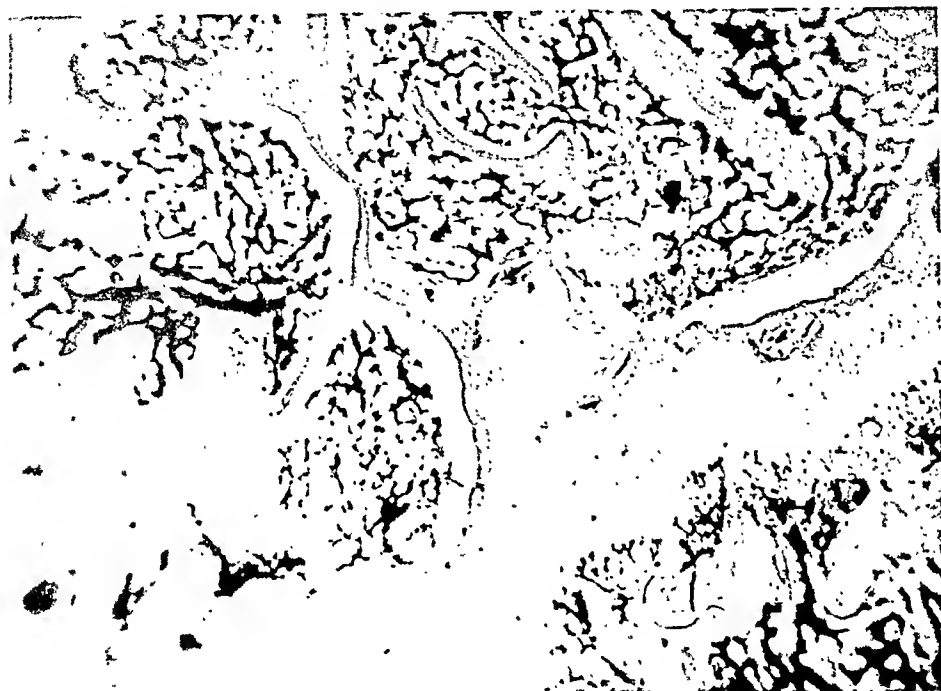
cartilage was wavy with some thick and some thin parts. In some cases the cartilage cells were in small areas numerous but irregularly arranged. The trabeculae showed marked variations in their arrangement; usually they were strikingly widely spaced with irregularly-shaped meshes; in other cases there was in small parts a closer, but still irregular arrange-



*Fig. 3.*

ment of the trabeculae, though there was still wide variation: some were rather thin, and seemed more primitive, others were thick. In these parts there was considerable osteoblast activity (fig. 3). An almost constant change was an irregular widening of the epiphyseal cartilage. Many times small mushroom-shaped outgrowths consisting of cartilage cells were found (fig. 4). In one preparation the medial part of the epiphyseal cartilage was penetrated by a cellular connective tissue, which seemed to be preparing the way for a callus-like tissue. In some preparations there were changes in the epiphyseal cartilage which must be considered as necroses: poor

and no staining of the nuclei. Similar changes were seen in the joint cartilage and in sections of the bony part of the head, where some cases showed definite necrosis (fig. 5). In one place an ingrowth from the marrow into the necrotic part was seen. The marrow was usually fibrosed. In cases which had been allowed to live several weeks after the in-

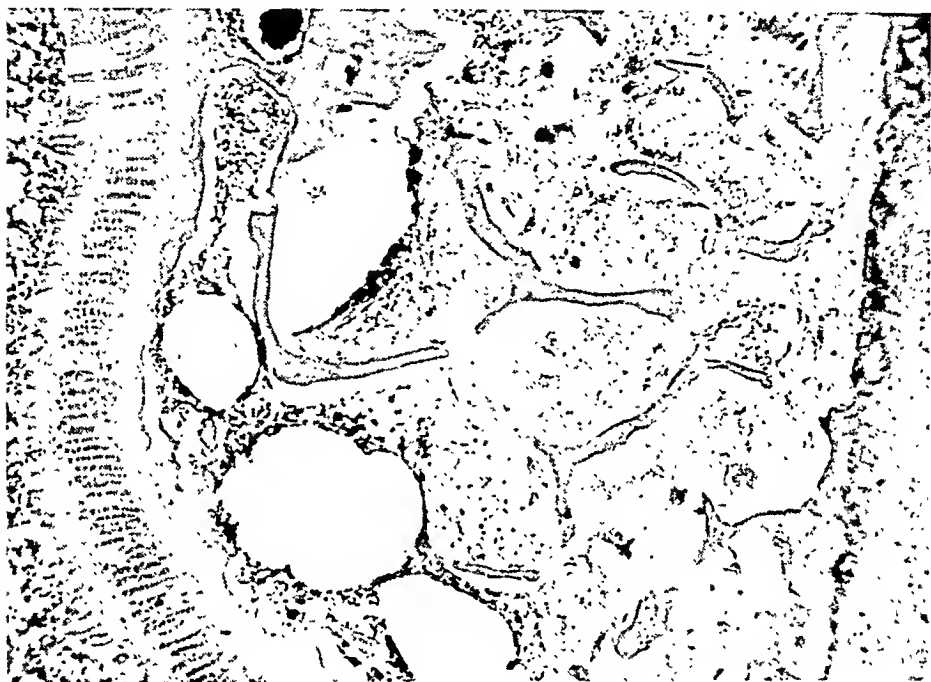


*Fig. 5.*

jections the marrow seemed to have been converted into fatty marrow, and, similarly, the other changes showed a tendency to return to normal. At the site of the injections there were marked changes most often consisting of tumor-like masses of a primitive tissue resembling cartilage.

Various injection and staining methods were attempted to demonstrate the condition of the circulation. Injection of red-lead-gelatine showed the course of the arteries, and confirmed that the main artery ran under the neck; other methods were also used. Indian ink-gelatine gave good pictures of the arrangement of the vessels. No new formation of vessels was

seen in the head, but there was rich proliferation of vessels round the site of the alcohol injections. When the vessels were artificially distended by the injection these methods gave no true impression of the degree of filling of the blood vessels. There were some technical difficulties in demonstrating the degree of filling, but staining the red blood corpuscles was



*Fig. 5.*

fairly successful (using a modification of Weigert's stain). No definite hyperaemia could be found in the treated hips.

In the 3rd series an attempt was made to produce an artificial hyperaemia by daily injections of procaine. No changes could be detected. The blood-filling was the same on the treated and untreated sides.

In the 4th series, 11 rabbits were used, and small fissures were made percutaneously in the femoral neck to study the importance of direct trauma. No changes were seen in the head.

In the 5th series Varex was injected round the vessels of

the femoral neck in a few animals, in the hope that the blood-supply might be interrupted. Again there were no results, and especially there were no areas of necrosis.

Thus changes were produced in the femoral head, and were more marked the younger was the animal and the greater the irritation. The changes consisted of those which are seen in the breakdown and repair of bone and which lead to changes in the shape and structure of the capital epiphysis.

It is not clear what kind of action is produced by the injection of alcohol round the neurovascular bundles. It does not seem that a significant hyperaemia occurs. But by analogy with experiences elsewhere one must assume that the alcohol interrupts the nerves and thus acts on the capital epiphysis. One cannot speak of a direct action, since it was injected at some distance from the head.

Are the changes which were produced identical with those of Calvé-Perthes' disease? One certainly cannot prove it, but it seems to me that there are so many features common to both that it is justifiable to base some ideas about the character and aetiology of the disease on the results: in animals, during growth, there have been seen macroscopical and radiographical changes, necroses, cartilage formation and regeneration processes, that is to say the same components which form the mixed histological pictures of Calvé-Perthes' disease, which we know from some, though only few, investigations. One cannot expect to produce an exactly similar disease picture in experimental animals in whom weightbearing is different and the disorder does not occur spontaneously.

As a result of my experiments I have come to the conclusion that the disorder consists of a disturbance of the natural growth of the bone, in which there is an interference with the factors that determine the normal differentiation of the cells and the structure and shape of the tissue.

About the differentiation of bone tissue we know so far, from work by *Fischer* and *Parker*, and *Fell*, and others, that it originates from a fibroblast-like cell without any special characteristics. However, this cell has the property, when the

conditions are suitable, of forming the starting-point for the cartilaginous skeleton and can further develop into bone cells. In in-vitro studies in which the primitive mesenchymal cell has been isolated from the parent organism it has been possible to make it differentiate so that a tissue is produced which is by no means unlike the corresponding supporting tissue in the parent organism. It seems, therefore, as if the primitive cell has the property of very advanced differentiation though not sufficient to form the different organs, and so to reproduce the organism. One cannot avoid the view that there must be a common regulating factor (which is not simply the same as the presumed growth hormone) which determines the development of the organs in an individual.

I suggest that it is at this point that in Calvé-Perthes' and similar diseases disturbance occurs and the controlling co-ordinating factor disappears. The bony tissue is then forced to take on a more primitive form of growth: cartilage is formed in preference to bone and the bone elements are found and arranged at random. Since this tissue is presumably less suited to weight bearing the affected parts of the bone are deformed according to the strains and trauma to which they are submitted.

Both clinical and experimental observations suggest that the process is not started by a single factor, but by a series of contributory causes. One may imagine that the regulation of growth is lost when the sum of these causes exceeds a certain limit.

Amongst them there is without doubt a constitutional, probably hereditary, factor. It is not possible to say what constitutes this factor, but it may be a matter of anatomical variations, e.g. in the course of the vessels and nerves, or a reduction in the stability with which the organism finds its shape. Thus the hip-joint is certainly a "locus minor resistentiae" in the locomotor system. The frequent occurrence of variations and the large number of arthroses suggest that there is a certain "incompleteness" of the hip-joint, a certain failure to stand up to the strain which is laid on it: from this



it is not far to the view that the "growth stability" of the joint is relatively small and can easily be upset.

Next we must point to the hormonal regulation. Here our knowledge is still very limited. We know the hormones which control the main tendencies of growth; we must find those which regulate the growth of different organs.

One must also consider the age. One can imagine that, at the time when the condition appears, there is a labile balance between the components of the joint—cartilage and bone—which can be upset by external factors.

Finally clinical experience suggests that trauma can play a part in the aetiology. This view is supported by the results of the experiments. But in the word 'trauma' I include all external factors of more than 'physiological' intensity, which cause a disturbance of the organism's normal function. Especially may one include small mechanical influences which under normal conditions will hardly have any harmful influence, but which, in special conditions, e.g. anatomical variations, can act on the mentioned growth-regulating factors so that the normal rhythm is disturbed. How far the point of attack is the nerves, how far the vessels, or perhaps quite other structures must be left undecided.

Thus it has not been possible to obtain an explanation of Calvé-Perthe's disease based on facts. Since I have included various unknown conditions in my discussion it cannot be considered as more than a hypothesis. However I hope that my experiments and ideas may form the basis for a more fruitful work on these problems. We can expect to get the final answer when the study of cells has elucidated growth and the determination of form; it will then be possible to test the views expressed here by more exact methods.

#### SUMMARY

By injecting alcohol round the vessels and nerves running to the femoral head in young rabbits macroscopic, radio-

graphie and histological changes similar to those of Calvé-Perthe's disease were produced.

From these findings it is suggested that Calvé-Perthe's disease is produced by a disturbance of the natural growth of bone tissue due to an action on the factors which determine the differentiation of the cells and the structure and shape of the tissue so that a more primitive form of growth predominates. The process is thought to be initiated by a number of causes, amongst which the constitutional, hormonal and traumatic are emphasised here.

#### RESUME

Au cours d'expériences pratiquées chez de jeunes lapins auxquels on a injecté de l'alcool dans les vaisseaux et les nerfs entourant la tête fémorale, on a réussi à provoquer des modifications qui tant au point de vue macroscopique, radiologique qu'histologique montrent beaucoup de ressemblance avec la maladie Calvé-Perthes.

Sur la base de ces recherches, il est allégué que la maladie Calvé-Perthes est due à une perturbation de la croissance normale du tissu osseux, à savoir une perturbation des facteurs qui conditionnent la différenciation des cellules, ainsi que la structure et la forme des tissus, les formes de croissance plus primitives devenant prédominantes. Toute une série de causes semblent pouvoir déclencher ces processus parmi lesquels on relève des facteurs d'ordre constitutionnel, hormonal et traumatique.

#### ZUSAMMENFASSUNG

Bei Versuchen, in denen jungen Kaninchen Alkohol um die zum Caput femoris laufenden Gefässe und Nerven injiziert wurde, wurden Veränderungen erzeugt, die makroskopisch, röntgenologisch und histologisch eine grosse Ähnlichkeit mit Mb. Calvé-Perthes zeigten.

Auf Grund dieser Versuche wird die Vermutung ausgesprochen, dass der Mb. Calvé-Perthes auf einer Störung des

natürlichen Wachstums des Knochengewebes beruht, in der Weise, dass die Faktoren, welche die Differenzierung der Zellen und die Struktur und Form des Gewebes bestimmen, beeinflusst werden, so dass primitivere Wachstumsformen dominieren. Man denkt sich, dass der Prozess aus verschiedenen Ursachen in Gang kommen kann, unter denen konstitutionelle, hormonale und traumatische Faktoren hervorgehoben werden.

#### DISCUSSION

*Bentzon, Thomasen, Morville, Stören, Sodeman, Randlov-Madsen.*

# THE GROWTH MECHANISM OF THE EPIPHYSEAL CARTILAGE IN THE LIGHT OF EXPERIMENTAL OBSERVATIONS<sup>1</sup>

BY

A. LANGENSKIÖLD & W. EDGREN

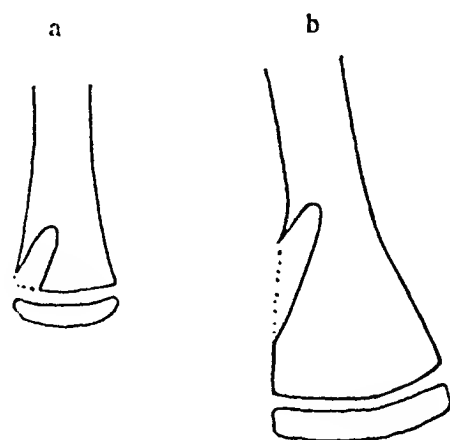
In an article on Ollier's disease published by *A. Langenskiöld* (*Acta orthop. scand.* 1947, 17, 93) the observation that the cartilaginous foci which appear in the skeleton in this disease develop in a characteristic manner was reported (Fig. 1). In another article (*Acta chir. scand.* 1947, 95, 367) it was suggested that this development is caused by a successive displacement of cellular elements from the central parts of the epiphyseal cartilage to its periphery transversely to the axis of the bone. It was assumed that this displacement occurs in normal bone growth in the layer between the bony epiphysis and the layer of cartilage cell columns. The osteogenic layer of the diaphyseal periosteum probably grows in length by means of a cellular material which is displaced from the interior of the epiphyseal cartilage. As this idea of the mechanism of normal bone growth can explain several phenomena in the pathology of bone growth it seemed desirable to try to elucidate the question experimentally.

The basis of the experiments was the idea, which has been stated previously, that Ollier's disease might be compared to an experiment by nature with "labelled cells" which only partly obey the laws of normal differentiation, growth and resorption. According to this idea it seemed probable that irradiation of limited portions of the epiphyseal cartilages

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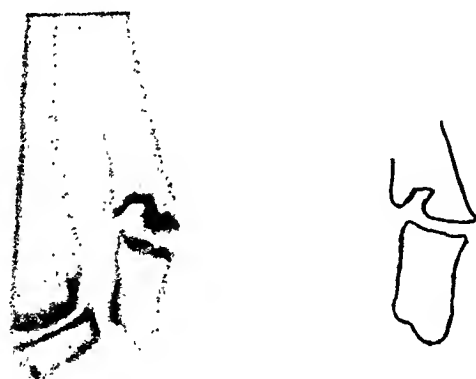
<sup>1</sup> A preliminary report.

with X-rays might produce foci which would be similar to those of Ollier's disease, and would undergo the same stages of development.



*Fig. 1.*

Schematic drawings illustrating the development of a cartilaginous focus in Ollier's disease. a) Stage II. b) Stage IV. These drawings were published before the experiments were begun (cf. *Acta chir. scand.* 1947).

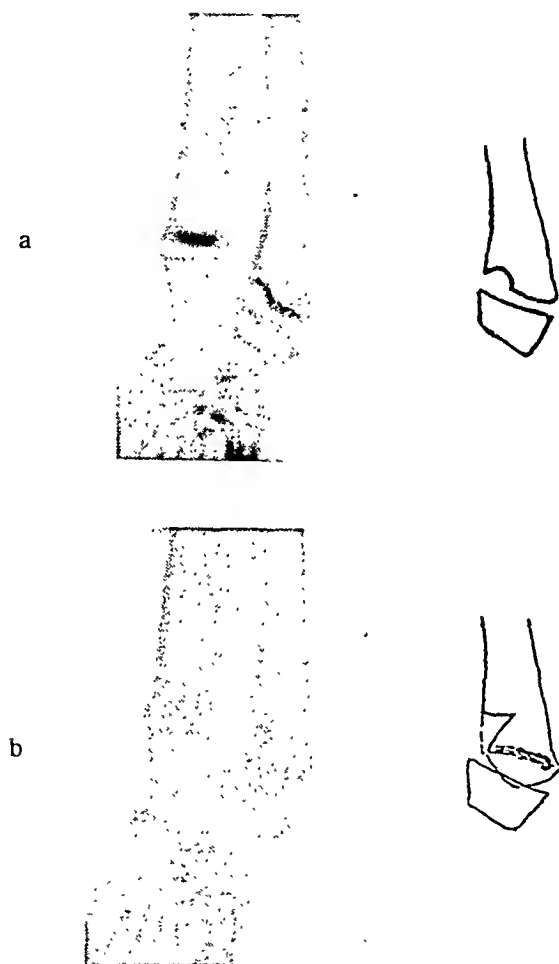


*Fig. 2.*

Radiograph of the antebrachium of a rabbit 41 days after localized X-ray irradiation. Beneath the radiograph a contour drawing of the ulna. Note the oblique position of the focus in relation to the diaphysis.

In rabbits aged 3-6 weeks, limited portions of the distal epiphyseal cartilages of the radius or ulna or both bones were

exposed to a single X-ray dose of 8000-20000 r. The growth was then followed by repeated X-ray-photography. It was found that ossification slowed down in the part of the meta-



*Fig. 3.*

Radiograph of the antibrachium of a rabbit. a) 26 days after localized X-ray irradiation, b) the same leg 49 days after irradiation. Beneath the radiographs, contour drawings of the radius.

physis which corresponded to the irradiated part of the cartilage. After 3-5 weeks the roentgenograms showed foci very similar to those seen in Ollier's disease (Fig. 2). These experimentally provoked foci developed with regard to their

shape, in the same manner as the Ollier foci. The epiphyseal end of a focus was gradually displaced towards the periphery of the epiphyseal plate and finally lost contact with it. At this stage the foci also appeared, in roentgenograms taken at a certain angle, as triangular notches in the periphery of the bones (Fig. 3). Perpendicular projections also showed the similarity to Ollier foci.

As the working-hypothesis has been proved correct, these experimental results may support the views on normal and pathological bone growth which were expressed in the articles already mentioned. Several other arguments, which cannot be discussed here, support this view, that in a certain layer of the normal epiphyseal cartilage, a migration of cellular matter occurs transversely to the axis of the bone. This displacement is assumed to play a rôle in any pathological process in epiphyseal cartilage.—In localized X-ray irradiation we may have a useful method for the study of growth processes. The detailed description of the experimental results with microphotographs and more roentgenograms will be published later in *Acta chirurgica scandinavica*.

#### SUMMARY

Using localized X-ray irradiation of limited areas of the epiphyseal cartilages of growing rabbits, the authors provoked foci, which, with regard to their shape, developed in the same characteristic manner as the foci in Ollier's disease. The results support the views on bone growth which were put forward by A. Langenskiöld in 1947.

#### RESUME

Par application localisée des rayons X à des parties limitées des cartilages epiphysaires des lapins en croissance les auteurs ont provoqué des foyers qui se développent à l'égard de sa configuration de même façon caractéristique que les foyers dans la maladie d'Ollier. Les résultats appuient les vues sur la croissance de l'os présentées en 1947 par A. Langenskiöld.

## ZUSAMMENFASSUNG

Durch lokalisierte Röntgenbestrahlung begrenzter Epiphysenknorpelpartien an wachsenden Kaninchen haben die Verfasser Herde provoziert, die sich in Bezug auf ihre Form in derselben charakteristischen Weise entwickeln wie die Herde bei der Ollier'schen Krankheit. Die Resultate stützen die Ansichten über das Knochenwachstum, die im Jahre 1947 von A. Langenskiöld ausgesprochen wurden.

## DISCUSSION

*Lütken, Silfverskiöld.*

*P. G. K. Bentzon*, Århus: referred to his publication in *Acta Radiologica* vol. 3 and said that in Ollier's disease one must regard diaphyseal "chondroma formations" as the most important element of the disease. The chondroma lines which can be shown corresponding with the nutrient foramina of the diaphysis can never originate in elements developed from the epiphyseal cartilage since the central parts of the bone are developed from the primary *diaphyseal* cartilage. *Bentzon* showed illustrations of this condition. (*Bentzon* will give a more extensive and detailed account of his view of Ollier's disease at Nordisk Ortopedisk Forening's meeting in Helsingfors 1949).

*A. Langenskiöld*: With reference to the radiograph shown by Dr. Bentzon we have reason to assume that the part of the tibia in which the proximal cartilaginous focus was situated had developed in its entirety from the proximal epiphyseal cartilage. This cartilage is responsible for a good half of the growth in length of the tibia. The oldest part of the diaphysis of the tibia corresponds to a level lying somewhat distal to the mid point of the bone.—The migration of cells which is assumed to occur in the layer of the epiphyseal cartilage which lies between the bony epiphysis and the layer of cartilage cell columns does not normally leave any trace in the structure of the metaphysis or in the central parts of the



cartilage. Only in certain pathological conditions do „oblique lines” occur in the metaphyses. These oblique lines are the traces left behind by the limits between normal and pathological tissues in the epiphyseal cartilage. This can be seen directly in histological sections of bones with foci provoked by localized X-ray irradiation.—Dr. Lütken has pointed out that foci corresponding to the type described in the previous papers as stage I. have not been provoked experimentally. This is true, but none of the conclusions drawn either here or in the previous articles are based on the assumption of the existence of this stage. On the contrary, it was previously emphasized that stage I must be considered hypothetical (*Acta orthop. scand.* 1947), whereas the assumption of the existence of stages II-IV is based on facts. The hypothesis of stage I is based on reports in the literature dealing with enchondromata of a less benign nature than Ollier’s disease.

Tissue migration of a type which may occur in the growth of the epiphyseal cartilage is common in embryonic development. This has been shown by V. Vogt (*Roux’ Arch.* 1929, 120, 384) by excellent experiments with labelled groups of cells. Vogt used vital staining to label round areas of the superficial tissue at the equatorial level of amphibian embryos in the gastrula stage. These stained spots developed into long stripes which gradually migrated from the equatorial level through the blastopore into the interior of the gastrula. Although the analogy between these stained stripes and the stripes occurring in the skeleton in Ollier’s disease and in multiple cartilaginous exostoses is striking, this phenomenon is of course no real additional evidence of the correctness of the conclusions concerning bone growth. It will only serve as an example for the sceptic who has a preconceived opinion that the occurrence of tissue migration is improbable.—For other particulars reference is made to the articles mentioned in the report.

## COXA VARA CONGENITA OR INFANTUM WITH PSEUDARTHROSIS IN THE NECK OF THE FEMUR

BY

F. LANGENSKIÖLD, Helsingfors.

To judge from the fact that in the Orthopaedic Hospital of the Invalid Foundation we have seen in 3 years 18 cases of coxa vara congenita, which is said to be very rare, it seems as if this deformity is more common in Finland than in other countries. Only 2 of the cases were children. In no less than 10 cases, there was a true pseudarthrosis in the femoral neck—a complication which is scarcely mentioned in the orthopaedic literature. The patients with pseudarthrosis are much more disabled than those with a simple coxa vara, and they constitute a special therapeutic problem.

At operation on these 10 cases I have tried to produce bony union between the head and the diaphysis without impairing the mobility of the joint; this has proved to be very difficult. In the first 4 cases an intertrochanteric osteotomy by *McMurray's* method was done. Bony union was not obtained, but the gait became somewhat better, probably due to the fact that after the operation the greater trochanter was situated rather lower than before. In the following 5 cases the femur was divided at the base of the greater trochanter, the upper end of the diaphysis was telescoped into the head vertically to its distal surface, and the trochanter was fixed to the lateral surface of the diaphysis. One of the patients is still in plaster of Paris. In 3 cases bony union has not been obtained. In the fifth case the intended position has been obtained, but the joint has ankylosed. In the last, the tenth case, the head broke

into pieces during the chiselling of the sclerotic bone, which in all cases formed the boundary between the head and the psendarthrosis. The head was removed and a *Withman* reconstruction performed. Possibly either this operation or a *Schanz* osteotomy will be the best solution of the problem.

#### DISCUSSION

*Nilssonne, Severin, Stören, Berntsen.*

## ON THE INTERNAL STRUCTURE OF THE MOTOR CELLS OF THE ANTERIOR HORNS AND ITS CHANGES IN POLIOMYELITIS

BY

LARUS EINARSON

The neurological problems connected with poliomyelitis are to a considerable extent stamped by neurocytology. By this statement I mean that the study of the internal structure of the nerve cells and of its changes is of pertinent importance to our knowledge of the structural pathogenesis of this disease. Moreover, the changes produced by poliomyelitis imply some very interesting cyto-biological problems, which we are now able to tackle by a considerably more exact staining technique than previously (see *Einarson* 1947). Further, I do not think we ever can obtain a fuller understanding of the effect of the poliomyelitis virus without due attention to the internal structure of the nerve cells and its histochemistry, because here we are undoubtedly dealing with a very intimate interaction between the component parts.

### I. ON THE NISSL SUBSTANCE AND THE CHANGES IN BASOPHILIA OF THE NERVE CELLS

An extremely important structural element of nerve cells is the so-called Nissl substance, which appears in the cytoplasm as strongly basophil, coarser or finer fragments or granular particles. Their distribution is very characteristic of the main structural cell types, but within each type it is profoundly influenced by the state of activity of the neuron. All motor cells, both in the spinal cord and in the entire brain

stem, which innervate striated musculature developed from the myotomes and the branchial arches, possess the so-called somatochrome, stichochrome distribution of the Nissl substance, and the anterior horn cells represent the prototype of this arrangement (see *Einarson* 1945). The progressive-selective staining of the Nissl substance and chromatin with gallo-cyanin-chromalum produces an extremely clear and characteristic cellular picture (the Nissl picture, see fig. 1), which is of fundamental importance in neurocytology, since it furnishes the most delicate and accurate criterion for the estimation of the state of neuronal activity as well as of every deviation from the normal (*Einarson*, 1945; *Einarson & Lorentzen* 1946).

During life the cytoplasm of the anterior horn cells must be regarded as a polyphasic colloidal system of a structure resembling a vesicular gel. Within it the Nissl substance constitutes an internal discontinuous phase including several components of various degrees of viscosity; thus it is itself a complex colloidal state. The external continuous phase must also be of a complex nature, since it contains at least two components, one of a somewhat lower viscosity (neuroplasm) and another of a considerably higher viscosity (neurofibrillar substance). The fixatives essentially precipitate the colloidal state of the living nerve cells, and the pattern obtained is a fairly true stiffened or fixed picture of the polyphasic gel-system of the cells, as it was at the moment of fixation (*Einarson* 1935, 1945).

Through a series of studies I arrived at the result that the material from which the Nissl substance is elaborated is formed primarily round the nucleolus inside the nucleus, migrates towards the periphery of the nucleus, and then diffuses gradually through the nuclear membrane to form Nissl bodies in the cytoplasm (*Einarson* 1933, p. 162). Ten years later this has been confirmed by *Hydén* (1943) by the aid of ultraviolet microscopy and absorption measurements.

I have also shown (*Einarson* 1932-1935) that the Nissl substance contains at least three different components, nucleo-

proteins (chromatin substance), acid and basic proteins respectively. The most important result was expressed as follows: "*The natural conclusion is that the Nissl substance contains some nuclein compounds,*" (Einarson 1935, p. 117). With this statement nothing was predicted as to the exact nature of the nuclein compounds in question, nor that the nueleins of the Nissl substance necessarily had to be chemically identical with those of the nucleus, in spite of their nuclear origin. My results were later confirmed by *Landström, Caspersson & Wohlfart* (1941) and by *Hydén* (1943), who have shown that the nucleic acid of the Nissl substance is of the ribose type and thus is different from that of the nuclear chromatin; this explains the negative Feulgen reaction of the Nissl substance.

Further, I have shown that the specific staining of nerve cells with galloeyanin-chromalum (*Einarson* 1932) depends on a stable chemical binding of the stain to the Nissl substance, especially to its nueleoprotein (*Einarson* 1934). Continued studies on the theory of staining (*Einarson* 1936, 1945; *Einarson & Bentsen* 1939; *Einarson & Lorentzen* 1946) led to the conclusion (*Einarson* 1947, p. 13) that the pure specific staining of the Nissl substance, the nuclear chromatin and the nucleolus is due to a chemical binding of the galloeyanin-lake-ion<sup>+</sup> to the nucleic acids of the structures and most probably to their phosphoric acid groups. When the pH of the staining solution lies on the acid side of the isoelectric point of the structures the binding of the lake-ion<sup>+</sup> to the nucleic acids is markedly specific; with a pH lying on the basic side of the isoelectric point, the stain also becomes linked to the proteins of the structures. The form of the nucleic acid does not affect the staining, i.e. the reaction is positive for ribonucleic acid as well as for desoxypentose nucleic acid (*Einarson* 1947). These results have now been confirmed and elaborated in some valuable papers by *Lagerstedt* (1947, 1948).

The consumption and resynthesis as well as the histochemical composition and quantity of the Nissl substance varies greatly with the state of activity of the neuron. Emph-

asis must therefore be laid on the changes in the staining intensity of the cells as evidenced by the occurrence of various degrees of chromophily and chromophoby (*Einarson* 1932-1937; *Einarson & Ringsted* 1938 etc.). It has been definitely established that this variation in the staining intensity depends directly on the inherent capacity to bind the stain, possessed by the living cell at the moment of fixation (see *Einarson* 1945; *Einarson & Lorentzen*, 1946). Since the galloeyanin-lake-ion<sup>+</sup> becomes linked selectively to the nucleic acids of the structural elements, the staining intensity gives a quantitative expression of their content of nucleic acid. Thus the degree of basophily of the different structures of the cell varies directly with their content of nucleic acid, and the staining can be used for its quantitative estimation on the basis of the principle of photometric determination, as I have already pointed out several times (see *Einarson* 1947, p. 14).

Many years ago I showed (*Einarson* 1937, p. 12-13) that the stages of chromophily and chromophoby involve a shift in the isoelectric point of the Nissl substance (as to the technique and for further information see *Einarson* 1945 and *Einarson & Lorentzen* 1946). In extremely chromophil cells the isoelectric point lies approximately at pH 1.9, while in extremely chromophobe cells it lies at pH 3.5. The maximum difference in the position of the isoelectric point thus corresponds to an electromotive force of approximately the same order of magnitude as the current of action. In chromoneutral cells the isoelectric point lies approximately at pH 2.7. The various components of the Nissl substance possess different isoelectric points, and the shift mentioned is due to a change in the mutual quantitative ratio between these constituents, mainly between the quantity of polynucleotides on the one side and basic proteins on the other.

As to the functional meaning of the various stages of chromophily and chromophoby I have, through a series of investigations since 1932 (for reference see *Einarson* 1945 and *Einarson & Lorentzen* 1946), arrived at the following main conclusions: The chromoneutral condition represents cells

at rest or in the usual state of gentle activity (*the indifferent phase of activity*); slight chromophily (*hyperchromasia*) characterizes cells when their activity begins to increase (*chromophily of initial activity*); while slight or moderate chromophoby gradually becoming more marked characterizes cells in increasing activity of longer duration (*chromophoby of prolonged activity*); the intense chromophoby is an expression of cells in fatigue (*chromophoby of fatigue*), and extreme chromophoby characterizes cells in exhaustion (*chromophoby of exhaustion; depression of fatigue*). On the other hand extreme chromophily characterizes either cells in a state of primary, active inhibition of prolonged duration (*chromophily of inhibition*), or cells, whose activity has been lowered or abolished for some time (*chromophily of depressed activity*).

Extreme chromophoby may be produced by prolonged irritation, by experimental fatigue (see *Einarson & Lorentzen* 1946), by experimental acute anoxia (see *Erik Krogh* 1945), as the initial effect of vitamin E deficiency (*Einarson & Ringsted* 1938) and by experimental insulin shock (*Lorentzen*, unpublished work); in human brains and spinal cords it also occurs in various diseases and toxic conditions, and it may reach such a degree as to resemble closely the most intense phase of chromatolysis. It may proceed to total dissolution of the cell.

Extreme chromophily may be produced experimentally by prolonged inhibition (*Einarson* 1933, 1945), by chronic sublethal anoxia (*Morrison* 1946), as the chronic effect of protracted vitamin E deficiency (*Einarson & Ringsted* 1938) and as the result of transneuronal degeneration (*Einarson & Lorentzen* 1946); it also occurs in various toxic conditions and diseases e.g. amyotrophic lateral sclerosis and chronic poliomyelitis, and it may gradually proceed to an irreparable cellular atrophy.

The classic example of chromatolysis is the so-called retrograde cellular change of *Nissl* which occurs after a lesion of the axis cylinder of the neuron (axon-reaction of the cell).



It is in fact a cellular reaction to the enormous demands for growth during the regeneration of the neuron. This regeneration from the condition of loss of substance involves a considerable increase in the consumption and resynthesis of cytoplasmic polynucleotides. Thus retrograde chromatolysis is a growth reaction, while chromophoby, due to prolonged hyperactivity, is a work reaction. Chromatolysis also occurs as the result of direct injury to the cell, as in various degenerative, toxic and infectious processes, e.g. in acute poliomyelitis; in such cases chromatolysis is an injury reaction (see *Einarson & Lorentzen* 1946).

Chromatolysis is in itself a reversible change, but it is not necessarily so. When restitution of the neuron does not take place, chromatolysis may either lead to acute total dissolution of the cell, e. g. in severe cases of acute poliomyelitis, or it may gradually proceed to extreme chromophily and finally to irreparable cellular atrophy, e.g. in chronic poliomyelitis (see below).

All the anterior horn cells shown in the figures of this paper (Figs. 1-12) were stained with a solution of gallocyanin-chromalum of pH 1.64 and photographed at a magnification of 600, under exactly identical conditions.

## II. ON THE CELLULAR CHANGES IN POLIOMYELITIS

### a) *Precursory remarks.*

The changes involved in the various phases of poliomyelitis largely illustrate the whole range of the most essential changes which the Nissl picture of the cells may display, and which may occur in other disorders or, as already mentioned, be produced experimentally in various ways. It is actually a question of structural stages in a general process of changes with which the cells respond to various noxious factors or experimental conditions.

On the basis of numerous investigations it must now be considered established that the cellular changes are primarily due to a direct, selective action of the virus on the nerve cells,

and that this is the real causative factor of the actual poliomyelitic paralyses; thus it is a question of a markedly neurocytotropic virus. The previously prevailing conception that the degeneration of the nerve cells was a secondary consequence of the inflammatory process must now be finally abandoned; a direct parallelism between the degeneration of the neurons and the inflammatory changes does not necessarily exist neither with regard to their intensity, localization, or distribution, nor with regard to the time at which they occur.

With the discovery of the selective neurotropism of the virus the study of the internal structure of the nerve cells and its histochemistry has become of far greater theoretical interest and importance in the research on poliomyelitis than one was previously inclined to believe. As an example of the intimate interaction between the nerve cells and their structural condition on the one hand and the poliomyelitis virus on the other, it is sufficient to mention the interesting observation made by *Howe & Bodian* (1941) that regenerating nerve cells show an increased resistance to the destructive action of the virus, i.e. that a nerve cell, which is in a chromatolytic state before the onset of the infection, is, to a high degree, protected against the virus.

#### b) *Acute changes.*

Numerous works on the changes of the anterior horn cells in poliomyelitis, based both on series of patients and on animal experiments, have been published, mainly on the acute changes and their rapid development.

The acute changes of the anterior horn cells are now well known, but by means of the selective staining reaction of the galloeyanin lake it is now possible to estimate their nature and importance more exactly than was previously the case.

They begin with swelling of the cell body and chromatolysis with dissolution and diffuse disappearance of the Nissl bodies (Figs. 2 and 3); the site of the nucleus in the cell may

become more or less eccentric, and the nuclear membrane often shows pronounced basophilia with nuclear caps (Fig. 3). As early as 24 hours after the experimental infection the chromatolysis is often very distinct (*Bodian, 1947*): the same applies to patients who have died shortly or immediately after the onset of the meningeal reaction of the preparalytic stage. As soon as the climax of the initial chromatolysis is reached the impulse activity ceases, and there is paresis of the muscular

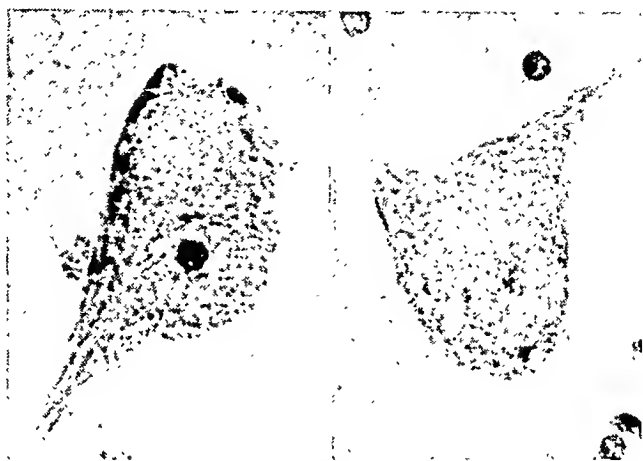


*Fig. 1.*

Normal, chromoneutral cell; somatochrom-stichoehrom pattern of the Nissl substance.

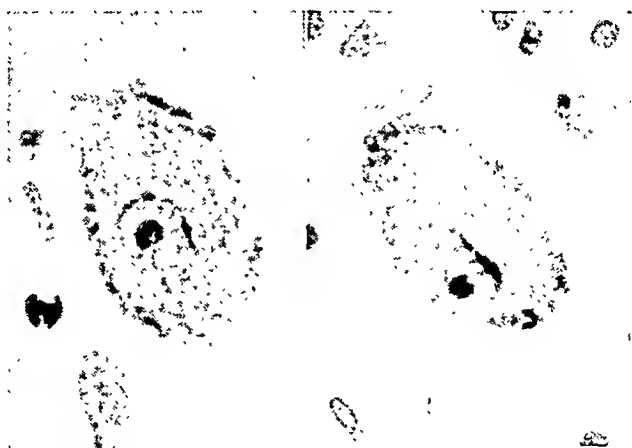
fibres innervated by the affected neuron. In the typical severe cases the changes progress rapidly with marked vacuolar breakdown of the cytoplasm and degenerative shrinkage and disappearance of the nucleus and nuclear membrane (Fig. 4). The contour of the cell assumes an irregular ragged appearance, the cytoplasm becomes structureless, frequently with relatively increased acidophily before it disappears altogether as a cell shadow (*einfacher Schwund, Horányi-Hechst, 1935*) or is destroyed by neuronophages. It corresponds, clinically, to the paralytic stage, with its rapid development of paralyses, which often reach their maximum after 24-48-120 hours. At the same time the microglia is mobilized, most frequently with occurrence of marked neuronophagia, which leaves behind more or less definite microglial nodules round the

severely degenerated cell remnants, or in the place of the nerve cell which has completely disappeared (Fig. 5). As already mentioned, the nerve cell may also be destroyed with-



*Fig. 2.*

Poliomyelitis; death almost 3 days after the onset of the paralyzes.  
Moderate chromatolysis.



*Fig. 3.*

Same patient as in fig. 2. Very pronounced chromatolysis, increased basophilia of the nuclear membrane and formation of nuclear caps; nucleus more or less eccentric.

out any noteworthy neuronophagia, at most with increased satellitosis or pseudoneuronophagia. In all cases it is the primarily damaged nerve cell that is secondarily dissolved by

the neuronophages: the primary degeneration of the nerve cell is a *conditio sine qua non* for the ensuing neuronophagia. Such changes are, of course, absolutely irreparable; and the patients who survive an acute stage resulting in such severe changes will of course be permanently disabled as far as the affected neuromuscular units are concerned.

On the other hand, the initial chromatolysis (Figs. 2 and 3) is a reversible condition, and the process need not necessarily proceed to the acute, severe, cellular dissolution mentioned above (Figs. 4 and 5). Accordingly patients who survive the disease with such comparatively mild lesions may recover from their paralyses. Any physician who has treated poliomyelitis patients knows that it is by no means rare for a totally paralysed, and even considerably atrophied, muscle to recover its function, either completely or partially. A typical example of partial recovery in an experimentally infected monkey was described by *Hurst* (1929). The acutely developed motor symptoms consisted of bilateral ptosis, paralysis of the right arm, and paresis of both legs. The animal was killed on the 35th day after the onset of symptoms, at which time a considerable partial restoration of function in the affected parts had occurred. Histologically there was a distinct degenerative loss of nerve cells in the areas of innervation of the muscles affected, while it was evident that the remaining nerve cells had regenerated, and many of them had even become completely normal. It is, of course, impossible to say with certainty afterwards to what extent the preserved nerve cells had been affected, but at any rate a certain reversibility was beyond doubt. Thus, a not inconsiderable chance of reversibility exists, and the reversibility of the changes of the nerve cells is an indispensable condition for subsequent training and restoration of function of a totally paralysed muscle. This applies quite apart from the fact that when only some of the anterior horn cells of a muscle have degenerated irreparably or completely disappeared, while others are fully preserved, it is possible to train the unaffected muscle fibres to such an extent that they can compensate the loss of the

severely affected neuromuscular units, if this loss is not too extensive.



Fig. 4.

Poliomyelitis; patient died from respiratory paralysis 5 days after the onset of the paralytic stage, with severe paralyses in all four extremities. Chromatolysis, swelling and acute vacuolar dissolution of the cell.



Fig. 5.

Poliomyelitis; death approximately 1 month after the onset of paralysis. Glial nodule at the site of a motor cell which has entirely disappeared by acute disintegration and neuronophagia.

*The chromatolysis is a structural expression of a radical change in the nucleic acid metabolism of the nerve cell, and the dissolution of the Nissl substance is tantamount to a breakdown and disappearance of the nucleotides of the cell. Using the staining technique employed here the quantitative*

*diminution of the Nissl substance is an indicator of the depletion of the nucleotides of the cell, for the galloxyanin-lake-ion is bound selectively to the nucleic acid component of the cellular structures, and the staining intensity gives a quantitative measure of the content of nucleic acid of the cell. The compact nucleolus, the intensely stained nuclear membrane with the accumulations of perinuclear substances and nuclear caps with a great content of nucleic acid are an expression of the nuclear resynthesis of polynucleotides and the persisting tendency to regeneration of the cytoplasmic nucleotides and proteins of the cells. In poliomyelitis it is the virus and its multiplication in the cell which produces the changes in the nucleic acid metabolism with the quantitative reduction in the content of nucleotides; the breakdown and depletion of the nucleotides of the cell may proceed to the point where total degeneration and death of the cell must necessarily occur.*

The multiplication of the poliomyelitis virus must, at least to some extent, depend on an increase in virus nucleoprotein, and it is possible that this increase takes place partly by a transformation of the nucleoproteins of the nerve cell. As far as I know we have so far no detailed knowledge of the relation between the growth and multiplication of the virus and the nucleic acid metabolism of the nerve cell.

During chromatolysis the content of phosphatase in the cytoplasm is considerably increased simultaneously with the breakdown of the polynucleotides. It is possible that the phosphatase has a dissolving effect on the virus and thus counteracts its multiplication, i.e., that there is an antagonistic interaction between the phosphatase system of the cell and the virus, upon which the outcome of the acute phase depends, i.e., whether it results in the destruction of the cell or of the virus while the cell is still viable; in the latter case it may be possible for the cell to regenerate. The fact that a previously chromatolytic cell exhibits an increased resistance to the action of the virus (*Howe & Bodian*) may possibly be explained by the increased content of phosphatase of the cell, which affects the penetration or the growth of the virus in

the cell. Whether this is true or not must be the subject of subsequent investigations.

c) *Chronic Changes.*

Although the acute attack of the disease may be limited to milder lesions with the possibility of later regeneration of the nerve cells, the final outcome of the process is not necessarily determined, *for during the regeneration, or immediately after, the cell may undergo a chronic, slowly progressive change, sometimes ending in totally irreparable cellular atrophy.* It is particularly these chronic changes I have made the subject of my studies.

As far as I can see from a review of the literature *Schwalbe* (1902) was the first to pay attention to the chronic stages of the disease and to subject the late changes to a more thorough and surveyable study. Apart from the total cellular dissolution, which is invariably a consequence of the acute severe changes (Figs. 4 and 5) *Schwalbe* classified the late cellular changes in the following main categories: 1) Pale cells with still visible nuclei or nuclear remnants, indistinct or atrophied processes, and absence of the Nissl substance, 2) Shrunken, intensely stained cells, sometimes with granular cytoplasm, otherwise as compact stained bodies, in which neither nuclei, nor processes are discernible, 3) Cells in all stages between the categories mentioned and normal cells, generally localized in the periphery of the lesion; 4) Cells which he described as "calcified". Furthermore, *Schwalbe* surveyed up to his own time the most important publications of histological examinations of the spinal cord from poliomyelitis patients who had died either in the acute stage, or subsequently from an intercurrent disease. In this connection we are especially interested in the cases with pronounced paralyses reported by *Leyden*, *v. Kahlden*, and *Kawka*. On their cases autopsy was performed from 5 months to 17 years after the first onset of paralyses, and the late changes described by *Schwalbe* were strongly represented.



It is, of course, very difficult to estimate the exact value of these older investigations owing to the very varied techniques in use at that time. As late as 1902 Nissl's technique was not commonly used in the laboratories, and even *Schwalbe* himself did not use it in his studies on poliomyelitis. In spite of their shortcomings the older investigations have shown *that lasting pareses and muscular atrophies may be the consequences of chronic cellular changes, and need not necessarily be due to an acute loss and neuronophagia of the cells.*

A very important contribution to the study of the chronic, persistent histological changes in experimental poliomyelitis in monkeys has been given by *Warburg* (1931). It is a study of the nervous system of 15 monkeys (*macacus rhesus*) with typical paralyses and atrophies. They lived for a period varying from 19 to 309 days after the first onset of symptoms. *Warburg* gives a detailed account of the changes in the connective tissue, vessels and glia in addition to the neuronal changes in the various regions of the nervous system. Here, however, we are interested only in the changes of the nerve cells, particularly the anterior horn cells. In 9 monkeys which survived the disease for periods varying from 40-84 days (7 were killed and only 2 died of the disease) the numerical loss of anterior horn cells varied, both from case to case and within the various segmental regions of the same spinal cord; the majority of the cells was, however, as a rule present in the tissue, although changed to a greater or lesser extent. The dominant cellular change was an intense hyperchromasia of both cytoplasm and nucleus with increased staining and distinctness of the dendrites. The Nissl substance could sometimes be seen as granular particles or small flakes, but most frequently its pattern was not discernible in the compact, intensely stained, and occasionally spindle-shaped cell body. *Warburg describes these cells as distinctly affected, but probably still viable, and they correspond closely to the cellular change which I have designated as extreme chromatophily (Figs. 8 and 9), and they are closely related to, or even identical with the cells which Hurst described as "recoverable". Furthermore,*

*Warburg* describes other cells with less intensely stained or pale cytoplasm and occasionally with a hyperchromatic nucleus, as well as cells which appear as extremely pale cell shadows with irregular contours. *Warburg* is decidedly of opinion *that these are cells which have definitively succumbed to the morbid process, and they are identical with what I have designated as progressive irreparable cellular atrophy* (Figs. 10, 11 and 12). In the monkeys which survived for periods varying from 242 to 309 days, and which were all killed, the two categories of cellular changes just mentioned were strongly represented, but the number of pale cell shadows had become relatively larger. In some places the numerical loss of cells was somewhat larger, while the preserved cells only presented "few deviations from the normal other than slight distortions of contour and of the fibrillar network, which was sometimes knotted and clumped" (*Warburg*, 1931, p. 1210). It is also noteworthy that in contrast to the animals which died early with acute severe changes and loss of cells, these late-surviving cases with chronic cellular changes showed mostly simple satellitosis and not actual neuronophagia. The same chronic changes were also observed by Horányi-Hechst (1935) in patients who died 27 and 30 days, respectively, after the first onset of the paralyse; he did not enter into the details of the problem, but just designated them as "fortschreitende Nervenzelldegenerationen im chronischen Stadium der Poliomyelitis".

The results of my own examinations of material from patients are in complete agreement with those of *Warburg's* examinations of the experimental material from monkeys. I shall merely add that the staining with gallocyanin-chromalum allows of a much more exact estimation of the cellular changes than the staining technique employed by *Warburg*. In the first place, I want to emphasize that I have made observations which decidedly favour the view that the extreme chromophily (Figs. 8 and 9) and the irreparable cellular atrophy (Figs. 10, 11, and 12) do not represent isolated, independent cellular changes, but that the chromophily gradually passes into in-

creasing cellular atrophy which ends in the formation of cell shadows. The same applies to the initial chromatolysis (Figs. 2 and 3). This also is not an isolated phenomenon, as there are cell forms (Figs. 6 and 7), which decidedly represent transitional stages from chromatolysis to extreme chromophily; it is thus possible to speak of a postchromatolytic chromophily. In the stages shown in Figs. 7-10 the cell may,



Fig. 6.

Poliomyelitis; death 14 days after the onset of paralysis. Chromatolysis has culminated and the cells are on their way to chronic irreparable atrophy.

however, undergo a diffuse fatty degeneration, which leads to irreparable cellular lipodystrophy in the same way as in amyotrophic lateral sclerosis and experimental vitamin E deficiency (see Einarson & Lorentzen, 1946, p. 62-63). *If the initial chromatolysis does not lead to acute, severe, cellular change with neuronophagia and total cellular dissolution, or the cell does not regenerate completely in the course of some months, the chromatolysis may change into a state of gradually increasing chromophily, which may become extremely intense, and in which the cell appears as a very intensely stained, compact body, which then undergoes irreparable atrophy and ends as a more or less pale, atrophic, or structureless cell shadow. Thus it is here a question of stages in a chronic*

progressive cellular change (see Figs. 2-3 and 6-12), the most characteristic structural feature of which is the varying staining intensity of the cell, i.e., its variable capacity of binding the galloxyanin-lake-ion, which is tantamount to a quantitative change of the nucleic acid content of the cell. *After the initial vigorous breakdown of the nucleotides of the cell, as evidenced by the chromatolysis, an active resynthesis and*

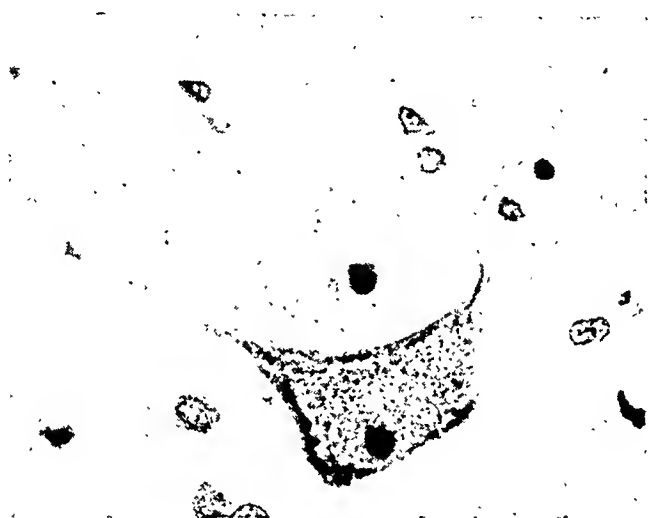


Fig. 7.

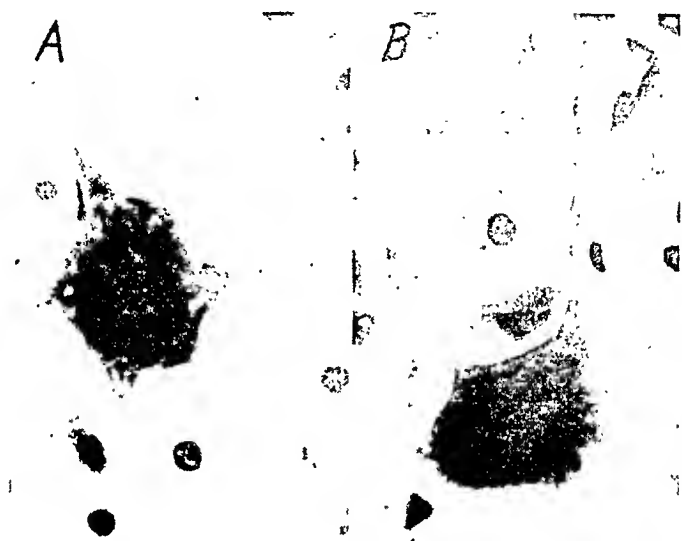
Poliomyelitis; death from intercurrent disease 40 days after the onset of rather mild paralyses showing marked tendency toward recovery.

Postchromatolytic restitution, the cell is becoming decidedly more chromophilic.

*gradual accumulation of nucleotides take place in the cell, the process, being manifested structurally by the increasing chromophily; the nucleotides then again gradually diminish and at last disappear completely, and the irreparable cellular atrophy is an expression of this stage.*

As far as these cellular changes are concerned, the question of their possible reversibility is of very great importance. It is a fact that the atrophic cell, the pale cell shadow, represents a stage of irreversible degeneration; it is a cell which has been finally destroyed, and this is also indicated by the designation *irreparable cellular atrophy* (Figs. 10, 11, and 12). However,

it is equally certain that the increasing intense chromophily represents stages which to a considerable extent are still reversible (Figs. 8 and 9). It cannot be determined at what stage the reversibility sets in, for we are as yet unable to draw a welldefined limit between extreme chromophily, cellular sclerosis, and cellular atrophy. However, numerous observations favour the view *that the extreme chromophily, which is*



*Fig. 8.*

Poliomyelitis; A) Patient died 3 months after the onset of paralyses which were mostly moderate. B) From another patient, who died 8 month after the onset of rather severe and widespread paralyses. The cells are in a still reversible state of extreme chromophily.

*always an expression of an accumulation of nucleotides in the cell, may persist for a long time as a still reversible state of the cell, and in my opinion this is not without importance in the aftertreatment of poliomyelitis.*

It must, of course, be realized that extreme chromophily also plays a rôle in other morbid processes, such as spinal muscular atrophy and amyotrophic lateral sclerosis, and here shows considerably less reversibility than in poliomyelitis. Chromophily may also be produced experimentally, e.g. by prolonged reflex inhibition (Einarson, 1933), where it is al-

ways reversible; by chronic vitamin E deficiency (*Einarson & Ringsted, 1938*), in which it is less reversible; by chronic intermittent anoxia (*Morrison, 1946; Erik Krogh, 1948*), where the reversibility is considerable; and finally as a transneuronal cellular change (*Einarson & Lorentzen, 1946*), in which it is more difficult to appreciate the degree of reversibility. The reversibility of the chromophily as a structural state thus



Fig. 9.

Same patient as in fig. 8 B. The most intense degree of extreme chromophily or cell sclerosis, a state possibly still reversible, at least the cell represented in A).

depends on the conditions under which it has arisen, and its tendency to develop into cellular sclerosis, cellular lipodystrophy, or irreparable cellular atrophy varies accordingly. As a cellular reaction in *poliomyelitis* the reversibility of the chromophily is, however, not very unfavourable, and extreme chromophily always denotes suppression or loss of physiological impulse activity, a state of inhibition.

When the cell enters the chronic state of extreme chromophily, it means that the impulse activity of the neuron is not initiated, and an important factor in the explanation of the chromophily must be that the formation of nucleotides con-

tinues in spite of the loss of impulse activity. This leads to an accumulation of these substances both in the perikaryon, the dendrites, and in the nucleus, as the increased dissimilative phase of the nucleotide metabolism connected with the impulse activity has been abolished, and the consumption of nucleotides is thus greatly reduced, i.e., the production is larger than the consumption. The result is *that the nucleic acid derivatives*

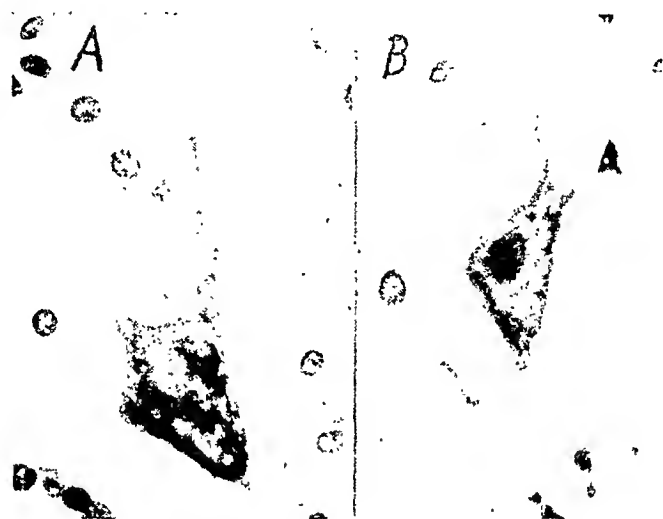


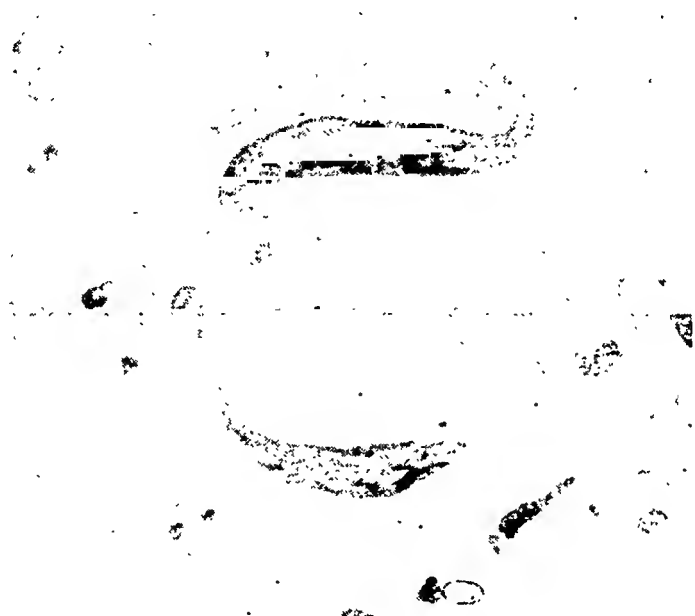
Fig. 10.

A) From the same patient as in fig. 8 B. and 9. B) From a patient, who died 11 months after the onset of the disease, with severe paralysis. Definitely irreversible cellular atrophy.

*so important to the impulse transmission and the metabolism of the neuron are not liberated in sufficient amounts, and that basophilic substance, for which the gallocyanin-lake-ion has such a strong affinity, accumulates in the cell. By degrees the new formation of nucleotides will cease, the already accumulated substance will disappear, while the cell proceeds to irreparable cellular atrophy. This assumption is strongly supported by the observation that when a neuron neither emits nor receives impulses, its cell body gradually enters into a state of extreme chromophily.*

d. *Discussion.*

My studies of the spinal cord from poliomyelitis patients who died after periods varying from some months to about 3 years after the acute stage of the disease, have shown that not nearly all the motor cells in the area of innervation of the paretic or atrophied muscles had disappeared or been



*Fig. 11.*

Poliomyelitis; patient died more than 2 years after the onset of the disease, with widespread paralyses in the lower extremities. Chronic, totally irreparable cellular atrophy.

absolutely irreparably changed. A surprisingly large number of cells was still present in a state of extreme chromophily, with the isoelectrical point of the Nissl substance lying below or around pH 2.0 (see *Einarson & Lorentzen*, 1946, p. 64). On the basis of our experimental studies it seems very plausible to conclude that functionally it is also here a question of cells, the impulse activity of which had been totally abolished, but which might have been activated again before they proceeded to irreparable cellular atrophy. In my opinion a motor



cell of the anterior horns may remain for a very long time (up to 12-20 months) in such a torpid state of extreme chromophily without being irreparably changed, and without the trophic control of the axon (the peripheral nerve) suffering any observable damage.

In many of the chronic cases the cells have, of course, died

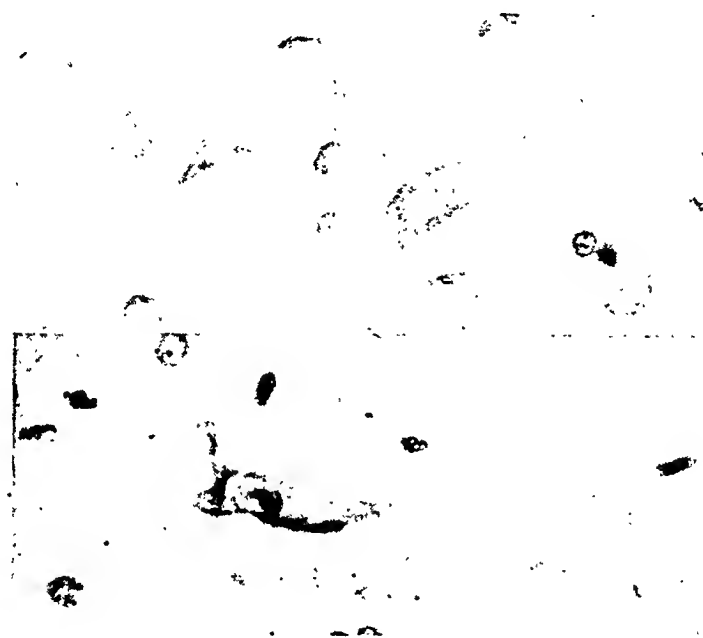


Fig. 12.

Same patient as in fig. 11. Chronic irreparable cellular atrophy and cell shadows.

or disappeared or passed into an irreparable state of atrophy, but it need not necessarily always be the case in spite of paralyses and muscular atrophies. Excellent results are now often achieved in orthopedic hospitals and sanatoria by physiotherapeutic treatment during the second stage of poliomyelitis, i.e., in the period between the acute stage and the occurrence of irreparable damage, and here it is very important to secure active physical and psychological co-operation on the part of the patient. *The results achieved in such institutions cannot exclusively be due to training and compensatory hypertrophy*

of such muscular fibres, whose area of innervation (the anterior horn cells) has escaped the acute breakdown, but must also to an essential degree be due to a reversibility of neuronal changes. In this connection I want to emphasize that in any training an important part is played by central-neuronal exercise or adaptation, i.e., the overcoming or lowering of synaptic resistances in the central nervous system. In my opinion the good results achieved with the aid of modern active physiotherapy are to no slight degree due to the circumstance that the systematically produced proprioceptive (*stretch reflexes*) and cerebrosfugal impulses which impinge on the neurons of the anterior horns will gradually release the motor cells from their torpid state of chromophily and thus again evoke their impulse activity. The synaptic resistance is overcome, the synapse is re-canalized for the impulses impinging on the cell, and its own impulse activity is re-evoked. The ensuing increase of the dissimilative phase in the nucleotide metabolism involves a consumption of the accumulated substances, and the state of intense chromophily is gradually abolished; concomitant with this process the demands for resynthesis of the cytoplasmic nucleotides increase. In other words, as soon as the impulse activity of the neuron is re-established, its nucleotide metabolism is activated. Thus the neuromuscular units whose anterior horn cells were extremely chromophilic, have a chance of recovery, while those whose cells were irreparably changed or have completely disappeared, will, of course, be beyond any possibility of recovery.

On the basis of numerous investigations it has been estimated that anterior horn cells with reversible changes may be restored to function in the course of from 1-20 months. Some authors, indeed, maintain (see e.g. *Hansson*, 1939, p. 32) that nerve cells which have been attacked by the virus and damaged without being destroyed, may recover in from 3 to 5 years; and cases of poliomyelitis have been encountered, in which completely paralysed and even markedly atrophied muscles have recovered after such a long time. I do not want to say anything as to whether the restoration of the muscular

function in such cases is connected with peripheral axon regeneration. I shall merely emphasize the remarkable primary resistance to the poliomyelitic process which myelin sheaths and especially axons possess. When the cells degenerate in the acute phase, the axons will, of course, rapidly be subjected to secondary degeneration; but if the cells are restituted after the acute chromatolysis, such axon changes do not occur. I shall also emphasize the disproportion existing between the intensity of the muscular changes on one hand and the peripheral nerve changes on the other, which is so often encountered in poliomyelitis and amyotrophic lateral sclerosis. Several years after the acute stage of the disease severe diffuse muscular atrophies concomitant with surprisingly slight changes in the peripheral nerves have been encountered in the chronic stage of poliomyelitis (see *Kopits*, 1929; *Horányi-Hechst*, 1935). This condition often coincides with the presence of ample amounts of extremely chromophilic and sclerotic cells in the anterior horns. Several authors believe that if the acute inflammatory process can evoke secondary slight changes in the nerve cells, the cells may recover in from 2 to 60 days (*Hansson*, 1939), but it is doubtful whether such cellular changes are of any importance at all.

#### SUMMARY

The structural changes of the nerve cells have been studied by the aid of the progressive, selective staining with galloyanin-chromalum, which allows a quantitative estimation of the basophilia of the cells. Since the stain becomes selectively bound to the nucleic acids of the structures, its intensity (chromophily, chromoneutrality, chromophoby) gives a fairly accurate expression of the cellular content of nucleic acids, which varies markedly in poliomyelitis as well as under experimental conditions (anoxia, vitamin E deficiency etc.).

In poliomyelitis the acute changes of the cells (swelling, chromatolysis, vacuolar dissolution, neuronophagia) are distinguished from the chronic or late changes (extreme chromo-

phily, cell sclerosis, lipodystrophy and irreparable cell atrophy), and both are estimated in relation to the varying cellular content of nucleic acids. In fact lasting pareses and muscular atrophies may be the consequences of these chronic cellular changes, and need not necessarily be due to an acute loss of the cells and neuronophagia.

Several observations support the view that the motor cells may remain for a long time in the torpid but still reversible state of extreme chromophily, without the trophic control of the axon suffering any noteworthy damage. The good results of the physiotherapeutic aftertreatment of poliomyelitis (the systematic training of paretic and atrophic muscles) often achieved in orthopaedic hospitals, are thought to be due, in no slight degree, to a release of the motor cells from their torpid state of extreme chromophily and a gradual recovery of their impulse activity. This applies quite apart from the fact, that it is possible to train the unaffected muscle fibers to such an extent that they may compensate the acute loss of the severely affected neuromuscular units, if this loss is not too extensive.

## RESUME

Les modifications structurales des cellules nerveuses ont été étudiées à l'aide de la coloration progressive, sélective à la gallocyanine-chromalum, qui permet d'effectuer une estimation quantitative de la basophilie des cellules. Depuis que la coloration est devenue sélective des acides nucléiques de ces structures, son intensité (chromophilie, chromoneutralité, chromophobie) donne une indication relativement exacte de la teneur des cellules en acides nucléiques, qui diffère notablement dans la poliomyélite ainsi que dans les recherches expérimentales (anoxie, déficience en vitamine E, etc.).

Dans la poliomyélite, les altérations aiguës des cellules (enflure, chromatolyse, dissolution vacuolaire, neuronophagie) se distinguent des modifications chroniques ou tardives (chromophilie extrême, sclérose des cellules, lipodystrophie et atro-

phie irréparable) et il est possible de déterminer le genre de modification devant lequel on se trouve par l'estimation de la teneur différente des cellules en acides nucléiques. En fait les parésies durables et les atrophies musculaires peuvent être la conséquence de ces altérations cellulaires chroniques et ne sont pas nécessairement dues à une destruction aiguë des cellules et à une neuronophagie.

Plusieurs observations appuient l'hypothèse que les cellules motrices peuvent rester très longtemps dans un état torpide d'extrême chromophilie encore réversible, sans que le contrôle trophique de l'axone en ait souffert sensiblement. Les bons résultats des traitements complémentaires physiothérapeutiques de la poliomyélite (l'entraînement systématique de muscles parétiques et atrophies) sont souvent obtenus dans les hôpitaux orthopédiques et ils sont probablement dus en grande partie au fait que les cellules motrices ont été arrachées à leur état torpide d'extrême chromophilie et qu'elles ont retrouvé graduellement leur activité d'impulsion. Il est d'ailleurs entièrement fait abstraction du fait qu'il est possible d'entraîner des fibres musculaires non atteintes à tel point qu'elles sont capables de compenser la destruction aiguë d'unités neuromusculaires sévèrement malades, à condition que cette destruction ne soit pas trop extensive.

#### ZUSAMMENFASSUNG

Die strukturellen Veränderungen der Nervenzellen wurden mit Hilfe der progressiven, selektiven Färbung mit Gallocyanin-Chromalum untersucht, die eine quantitative Schätzung der basophilen Substanzen der Zellen gestattet. Da der Farbkörper sich ausschliesslich mit den Nucleinsäuren der Strukturen verbindet, ist ihre Intensität (Chromophilie, Chromoneutralität, Chromophobie) ein ziemlich genauer Ausdruck des zellulären Gehalts an Nucleinsäuren, der sowohl bei Poliomyelitis wie unter experimentellen Bedingungen (Anoxie, Vitamin E-Mangel usw.) beträchtlichen Schwankungen unterworfen ist.

Bei der Poliomyelitis werden die akuten Veränderungen der Zellen (Aufquellen, Chromatolyse, vakuolare Auflösung, Neuronophagie) von den chronischen oder Spätveränderungen (extreme Chromophilie, Zellensklerose, Lipodystrophie und irreparable Zellenatrophie) unterschieden, und beide werden im Verhältnis zu den Schwankungen des Zellengehalts an Nucleinsäuren geschätzt. Tatsächlich können dauernde Paresen und Muskelatrophien die Folgen dieser chronischen Zellveränderungen sein und brauchen nicht notwendig auf einem akuten Verlust der Zellen und Neuronophagie zu beruhen.

Mehrere Beobachtungen stützen die Ansicht, dass die motorischen Zellen längere Zeit in einem starren, aber immer noch reversiblen Zustande extremer Chromophilie verbleiben können, ohne dass die trophische Kontrolle des Axons irgendwelchen nennenswerten Schaden erleidet. Die guten Resultate der physiotherapeutischen Nachbehandlung der Poliomyelitis (die systematische Übung der paretischen und atrophischen Muskeln), die in den orthopädischen Krankenhäusern oft erzielt werden, müssen wohl in nicht geringem Grade auf einer Auflockerung des starren Verweilens der Zellen in extremer Chromophilie beruhen und auf einer gradweisen Wiedererlangung ihrer Reiztätigkeit. Dies gilt ganz abgesehen von der Tatsache, dass es möglich ist, die nicht angegriffenen Muskelfasern soweit zu trainieren, dass sie den akuten Verlust der schwerer angegriffenen neuromuskulären Einheiten kompensieren können, wenn dieser Verlust nicht zu ausgedehnt ist.

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NOTES ON THE HISTOCHEMICAL ASPECT OF THE  
CHANGES OF THE SPINAL MOTOR CELLS IN ANOXIA,  
VITAMIN E DEFICIENCY AND POLIOMYELITIS

BY

LARUS EINARSON

I. INTRODUCTION

The investigations on which the following notes are based have been carried out mainly by means of the progressive selective staining reaction of gallocyanin-chromalum (*Einarson*, 1932) supplemented by some other histochemical determinations; they will be published in detail in subsequent papers. It is sufficient to say that by means of photometric measurements staining with gallocyanin-chromalum allows a quantitative estimation of the basophilia of the cells. Since the stain becomes selectively bound to the nucleic acids of the cell structures, the staining intensity, as expressed by the states of chromophily, chromoneutrality and chromophoby respectively, gives a fairly accurate measure of the nucleic acid content of the cells (*Einarson*, 1934, 1945, 1947; *Einarson & Lorentzen* 1946; *Lagerstedt* 1947, 1948). This content is considerably altered in anoxia and vitamin E deficiency as well as in the changes following poliomyelitis. Thus the degree of the staining intensity depends directly on the inherent capacity of the cell to bind the stain: this depends on its content of nucleic acids, which is profoundly influenced by the state of functional activity of the neuron: the latter shows an intimate correlation with the structural stages of chromophily and chromophoby (for reference see *Einarson*, 1945 and



1949). It is sufficient to say that the various stages of chromophoby represent cells in increasing and prolonged activity, while extreme chromophily represents cells whose impulse activity has for some time been depressed or totally abolished. Since the Nissl substance is composed of nucleoproteins, acid and basic proteins respectively (*Einarson*, 1935), the stages of chromophily and chromophoby involve a shift in the isoelectric point of the Nissl substance (*Einarson*, 1937, 1945), due to a change in the mutual quantitative ratio between its nucleic acids (polynucleotides) on the one hand and its basic proteins on the other.

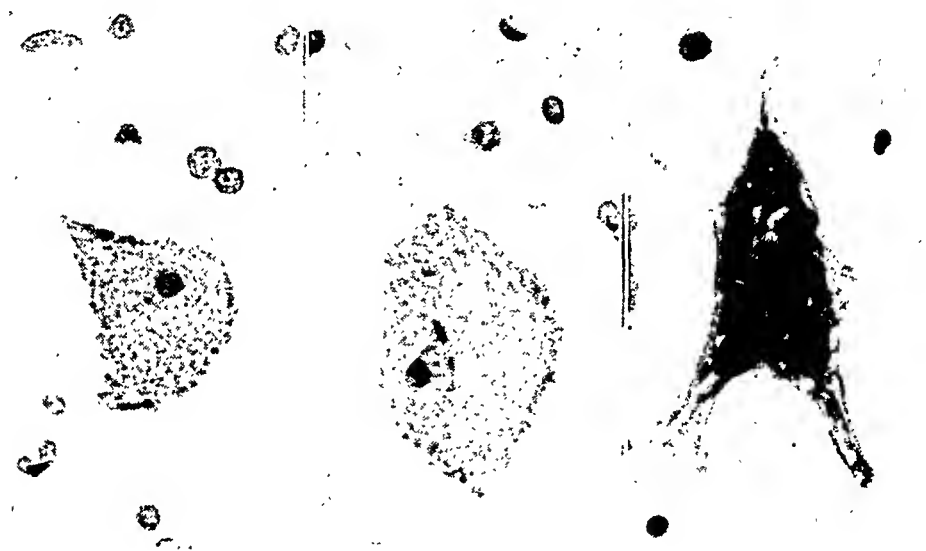
These intracellular and functional conditions of the neurons are profoundly altered in the structural changes following anoxia, vitamin E deficiency and poliomyelitis, and I think it is of some interest to investigate their mutual relationship in terms of their histochemical correlate.

## II. ANOXIA AND VITAMIN E DEFICIENCY

Changes of the anterior horn cells similar to those described in poliomyelitis (see *Einarson*, *Acta orthopaed. scand.* 1949) may also be produced experimentally by anoxia (*Erik Krogh* 1945; *Morrison* 1946) and by vitamin E deficiency (*Einarson & Ringsted* 1938).

The initial effects of both anoxia and vitamin E deficiency are always swelling and chromophoby of the nerve cells, accompanied by hyperexcitability and spastic rigidity of the muscles. Many years ago it was established, and has since been confirmed several times (see *Einarson & Lorentzen*, 1946), that anoxia of an intensity sufficient to produce spasms and convulsions need not be either so pronounced or so prolonged as to produce irreparable cellular changes or necroses. A short acute anoxia will invariably produce an initial state of excitation, which may be more or less pronounced before the activity is paralysed. As a morphological expression the initial chromophoby corresponds to this state of excitation, i.e., a more or less pronounced breakdown and disappearance

of the polynucleotides of the cell take place (see fig. 1). A more prolonged, intermittent anoxia, which is not sufficient to produce disintegration and necrosis of the cells (sublethal anoxia), will, on the other hand, lead to extreme chromophily accompanied by paralysis of the impulse activity, and gradually later to cellular atrophy; the same is true of the prolonged effect of chronic vitamin E deficiency (see fig. 1). If the



*Fig. 1.*

- A) Motor cell in extreme chromophoby, representing the initial structural effects of vitamin E deficiency and acute anoxia respectively.
  - B) Motor cell showing the initial chromatolysis of acute poliomyelitis.
  - C) Motor cell in an early stage of extreme chromophily representing the late or retarded structural effects of chronic, sublethal anoxia, protracted vitamin E deficiency and chronic poliomyelitis respectively.
- Galloeyanin-chromalum, pH 1.64  $\times$  600.

anoxia is initially either too intense or too prolonged, the nerve cells will, of course, be totally destroyed by a rapidly progressing degenerative process.

How are the structural effects of anoxia to be explained? There is no doubt that the necessary nucleic acid derivatives, which are so important in the metabolism of the neuron and for the formation of acetylcholine, originate from the de-

composition of the nucleic acids of the cytoplasm, which are in turn re-formed from the nucleus of the cell (Einarson, 1933, 1945). It appears that the presence of rather ample amounts of adenosine triphosphate (ATP) is required in the nervous system, presumably in connection with the great consumption and resynthesis of acetylcholine. ATP is constantly re-formed by liberation of adenylic acid from the stored polynucleotides of the cytoplasm (the Nissl substance) and subsequent phosphorylation of the liberated acid. This process will be particularly evident when there is a highly increased and prolonged impulse activity with its concomitant intense decomposition and resynthesis of acetylcholine, for then the stored polynucleotides, which may be demonstrated histochemically, are consumed (see the diagram fig. 2). The constant trophic maintenance of the structural integrity of the axon must presumably make heavy demands on the metabolic-chemical work of the nerve cell, but it must be assumed that during the normal resting phase the presence of phosphocreatine as a phosphate-donor reserve is sufficient to secure constant re-phosphorylation of ATP, as in muscles. During the enormous growth requirements in connection with regeneration of the neuron this is scarcely the case, for then the gray substance of the anterior horns loses about 40 % of its normal content of phosphocreatine. (Bodian, 1947, p. 172). Simultaneously the heaviest decomposition and consumption of the stored polynucleotides of the cell occurs, as evidenced by chromatolysis, and undoubtedly has a certain relation to the liberation of important nucleic acid derivatives such as adenylic acid. *In the adult organism, the cells of no other tissue contain such large amounts of cytoplasmic polynucleotides as the nerve cells, and this must be explained by the special metabolic conditions of the neurons, since these substances are being constantly decomposed and re-formed in close correlation with the functional and trophic activity of the neuron* (Einarson, 1933, 1945; Einarson & Lorentzen, 1946).

It is possible that nerve cells possess depots of chemically-

bound oxygen, which are utilized during the short initial state of excitation following anoxia, with its concomitant increased requirements on decomposition and resynthesis of acetylcholine (chromophoby). But it is equally plausible to assume that, during the brief period of excitation, the nerve cells are capable of mobilizing anaerobic energizing processes, and through these, if only for a very short time, are able to satisfy the acetylcholine requirements. The extreme chromophily of chronic, sublethal anoxia is tantamount to a paralysis of the impulse activity of the neuron; here the energy reserves, whether they are depots of chemically-bound oxygen or due to anaerobic processes, must be exhausted, so that the nucleic acid derivatives necessary for the resynthesis of acetylcholine are not split off from the polynucleotides of the cytoplasm, and these consequently accumulate in the cell owing to the still active production of nucleotides from the nucleus (see the diagram fig. 2). Now, it has also been found (*Stone, Marshall & Nimms, 1941; Gurdjian, Webster & Stone, 1944*) that the content of phosphocreatine and ATP in the nervous system is considerably reduced during anoxia and after experimental head and brain injury.

How are the structural effects of vitamin E deficiency to be explained? It has now been established that vitamin E inhibits oxidation; thus it protects certain substances (fatty acids, vitamin A) against oxidation. In vitamin E deficiency the oxygen consumption of the tissues is enormously increased; so that vitamin E must either have some control over the tissue respiration, or diminish the oxygen consumption (*Victor, 1934; Houchin & Mattill, 1942; Houchin, 1942*). In vitamin E deficiency, administration of the relatively water-soluble  $\alpha$ -tocopherol phosphate will rapidly reduce the oxygen consumption to the normal level (*Houchin & Mattill, 1942*), and it may be important that phosphorylation of the tocopherol, by which it is transformed into a water-soluble compound, takes place in the organism. The initial structural effect of vitamin E deficiency, the pronounced chromophoby of the nerve cells, may thus be explained by the removal of

a factor inhibiting oxidation: thus the tissue respiration cannot be kept at the level of the resting phase, and the polynucleotides stored in the cell must necessarily be decomposed under the increased requirements on the metabolism and the resynthesis of acetylcholine, as in acute anoxia. Similarly, it is possible to explain the chronic structural effect of prolonged vitamin E deficiency, the extreme chromophily of the nerve cells, by the fact that the highly increased oxygen consumption will lead to an exhaustion of the energy reserves of the cells and to the gradual development of a chronic sublethal anoxia with the ensuing accumulation of cytoplasmic polynucleotides and an arrest of the resynthesis of acetylcholine. Our own investigations, which I shall not mention here, show *that in prolonged vitamin E deficiency the phosphocreatine and the ATP content of the gray substance of the nervous system diminish considerably and finally disappear as the state of deficiency leads to irreparable cellular atrophy* (Einarson, unpublished work). Furthermore, it has been found that in rats on a low-fat, vitamin E-free diet, administration of tocopherol increased their resistance and prolonged their survival time under anoxia; increasing the fat content of the diet shortened the survival time under anoxia (Howe, Hickman & Harris, 1945).

Several investigators have pointed out that vitamin E probably also has some special tissue affinity and thus has a protective or antidystrophic action on tissues. On a diet low in vitamin E, or high in unsaturated acids, which bind or attack the vitamin, the tissues become dystrophic (see Einarson & Ringsted, 1938; Einarson, 1941) but only a very slight amount of vitamin E is necessary for their protection. Eppstein & Morgulis (1941 and 1942) found that the minimum antidystrophic daily dose in the rabbit was 200-400  $\gamma$   $\alpha$ -tocopherol (ca. 0.32 mg) per kg body weight. Einarson & Ringsted (unpublished data) found that in a 30-day-old common white rat the minimum dose necessary for protection against neuromuscular disturbances is as low as 25-50  $\gamma$   $\alpha$ -tocopherol per day. I have made certain observations which suggest that,

owing to its special tissue affinity, vitamin E is an instrumental factor in the liberation of adenylic acid from the cytoplasmic polynucleotides of the nerve cells (Einarson, unpublished work), and thus is more closely involved in the synthesis of acetylcholine than is generally assumed. If we accept that the decomposition of pyruvic acid occurs under the agency of  $H_3PO_4$ , by which acetylphosphate is formed, then the acetyl phosphate may be of central importance in the synthesis of acetylcholine. It may act partly as an acetyl donor and partly as a powerful phosphate donor, which in

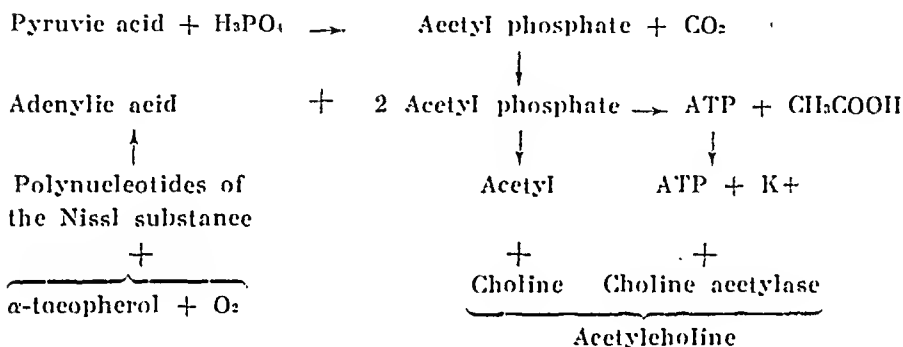


Fig. 2.

Diagram illustrating the assumption that  $\alpha$ -tocopherol acts by stimulating the liberation of adenylic acid from the polynucleotides of the Nissl substance, and its consequent importance in the formation of ATP and the synthesis of acetylcholine. See text.

the presence of free adenylic acid will form the ATP necessary for the synthesis of acetylcholine (see the diagram fig. 2). Undoubtedly the free adenylic acid is to an essential degree formed by the direct decomposition of the cytoplasmic polynucleotides (the Nissl substance) of the nerve cells, and it is in this primary liberation of adenylic acid that vitamin E plays a role owing to its tissue affinity.

As a working hypothesis this is in harmony with the essential structural effect of vitamin E deficiency, the tissue dystrophy, which is so characteristic in the gray substance of the nervous system, in the muscles, and in the seminiferous epithelium of the testicles. That vitamin E may be involved

in a special way in acetylcholine metabolism is suggested by the fact that in the neuromuscular dystrophy produced by vitamin E deficiency the content of cholinesterase of the atrophic muscles is very considerably reduced (*Stoerk & Morpeth, 1944*). It has also been maintained that  $\alpha$ -tocopherol stimulates the synthesis of acetylcholine (*Torda & Wolff, 1945*), and in my opinion this is due to its action in promoting the liberation of adenylic acid for the production of ATP. *Whether the chronic structural effect of vitamin E deficiency is due to removal of a factor inhibiting oxidation or to a defective occupation of special tissue affinities, it will always histochemically manifest itself by a reduced decomposition of the polynucleotides of the nerve cell and by a defective liberation of adenylic acid; this is the gist of the matter.*

### III. POLIOMYELITIS

How, then, are the structural effects of poliomyelitis to be explained? The initial chromatolysis and the subsequent acute cellular dissolution are due to a direct action of the virus (see *Einarson, 1949*). However, this can scarcely be the case in the chronic changes (extreme chromophily, lipodystrophy, cellular atrophy), since these do not occur until later, when the acute changes have passed, or in close relation to the regeneration of the nerve cells; thus the chronic changes are secondary, as compared with the acute ones. We might possibly speak of an indirect effect or an after-effect of the virus.

Which factors can be surmised to be instrumental in the development of the chronic changes of the anterior horn cells? In my opinion, three possibilities ought especially to be considered, namely:

- 1) The changes are due to a secondary chronic, sublethal anoxia,

or

- 2) There is a defective utilization of vitamin E (dysvitaminosis), in which a surplus of vitamin E must be

supplied to the nerve cells for the restoration of their normal activity,

or

- 3) We are dealing with transneuronal cellular changes (see *Einarson & Lorentzen*, 1946) due to a primary injury of spinal internuncial neurons and reflex pathways.

Chromophoby is a cytological expression of increased impulse activity, and must be associated with an increased decomposition and resynthesis of acetylcholine. In the same way, extreme chromophily and cellular atrophy are always, whether they are due to sublethal, chronic anoxia, vitamin E deficiency, or transneuronal degeneration, expressions of interrupted impulse activity and must be associated with reduced or arrested decomposition and resynthesis of acetylcholine. Irrespective of which of the three factors plays the most important rôle in the pathogenesis of the chronic changes, it seems to me to be worth while, as part of the after-treatment of poliomyelitis, to administer large doses of vitamin E simultaneously with the physiotherapeutic treatment and training of the muscles. *From a theoretical point of view it is not impossible that the administration of vitamin E might be an adjuvant to the physical training and orthopaedic support of the paretic muscles, and I would recommend a dose of 30-60 mg  $\alpha$ -tocopherol by mouth daily over a long period (1 to 2 years).* New evidence, both clinical and experimental supports the view that  $\alpha$ -tocopherol should be given by mouth; the parenteral administration of the vitamin is less effective, suggesting that  $\alpha$ -tocopherol undergoes some important changes in the gastro-intestinal tract (see, e.g. *Milhorat & Bartels*, 1945). It will, of course, be difficult to evaluate the results, but nevertheless one must ask why vitamin E should not be given during the acute stage of the disease, or even as a prophylactic, especially to persons who have been in contact with poliomyelitis patients or live in their immediate surroundings. In this connection I want to cite the following statement of *Bicknell & Prescott* (1942, p. 553): "*Sabin &*



*Duffy* from experimental work on young mice believes that vitamin E plays a part in the resistance of the nervous system to virus infections. *Einarson & Ringsted's* experimental work stresses that the lower motor neurons degenerate when there is a deficiency of vitamin E. These two observations suggest that vitamin E might be of value in increasing the resistance of children to infantile paralysis."

Incidentally, it is possible that the suggested vitamin E treatment should be combined with the administration of factors from the vitamin B group. In this connection I will mention the work of *Millhorat & Bartels* (1945), which indicates that the utilization of  $\alpha$ -tocopherol in patients suffering from muscular dystrophy is increased by the simultaneous administration of inositol. The combination of both these factors was found to be many times as effective in reducing creatinuria as wheat germ oil alone, and both factors should be given by mouth.

It is possible that a tocopherol-inositol condensation product is formed in the gastrointestinal tract, and that the constitutional defect in muscular dystrophy is a defect in this process of condensation, and that the patients need the condensation product itself. *It might therefore be worth while to administer an extract of hog stomach and duodenum (ventriculin, pylorin) simultaneously with  $\alpha$ -tocopherol and inositol, and this treatment should be tried not only in cases of muscular dystrophy and spinal atrophy, but also in poliomyelitis.*

Actually, this is in full agreement with the view, expressed 11 years ago by *Einarson & Ringsted*, that some components of the vitamin B complex might require the coexistence of vitamin E for their action, and that it would be conceivable that a certain balance between factors of the B group on one side and vitamin E on the other side (*Einarson & Ringsted*, 1938, p. 153) may be necessary.

Finally, I want to add a few remarks on the vulnerability of the motor cells in relation to their localization in the anterior horns. It was recognized long ago that the various

cell groups are not affected to the same degree, and attempts have been made to explain this fact by the distribution of the vessels within the anterior horns, as it was thought that the distribution and extent of the process was conditioned by the various architectonic vascular areas. This explanation is, however, untenable, for within the same vascular area some of the cells of the groups in question may be severely affected, while others remain normal. The explanation of the varying degree of vulnerability has therefore been sought in the hypothesis that the individual cells possess varying degrees of resistance or susceptibility at the onset of the disease, and that such conditions may play a certain rôle. Obviously, if the process is of sufficient intensity, all the cells may be affected and destroyed almost simultaneously. Hence the varying vulnerability of the cells will be most apparent in cases where the process is less intense and less widespread.

On reviewing the literature I found certain common features with regard to the localization of the most vulnerable cells in the anterior horns, which are in full agreement with my own observations. Thus *Schwalbe* (1902, p. 492-494) reported that when the process was of a moderate extent, it was the cells localized in the central parts of the anterior horns which were first affected, and that there was a marked tendency for the process to spread upwards and downwards in the central parts of the anterior columns. On the other hand, the cells localized along the outer periphery of the anterior horns were much better preserved; incidentally, *Schwalbe* found that the medial cell groups were slightly more vulnerable than the lateral groups. Practically the same findings have later been reported, e.g. by *Horányi-Hechst* (1935, p. 34-35). *Warburg* (1931, p. 1208-1211) described exactly the same findings in her material of experimental, chronic poliomyelitis and concludes by saying: "*There was also a variable number of cells approximating the normal, generally near the periphery of the anterior horns*". Finally, *Elliot* (1945) found that the dorsomedial cell group was the first to be affected, and that the process spread from here, via the central part

of the anterior horn, in the direction of its ventrolateral periphery, so that the cells along the periphery were preserved for the longest time. *In my own material I have found ample evidence of the fact that the nerve cells in the central parts of the anterior horns are most vulnerable to the poliomyelitic process, and therefore they are attacked first, whereas the cells along the periphery are more resistant and accordingly the last to be attacked.*

How is this very important fact to be explained? Here it is of importance that the same picture, i.e., breakdown and atrophy of the central cells with preservation of the peripheral cells, may be produced experimentally with considerable accuracy. Thus *Einarson & Ringsted* (1938) produced this picture of the anterior horns in adult rats by experimental chronic vitamin E deficiency. The cells localized at the periphery of the anterior horn, which are more resistant to this deficiency, innervate principally the extensors (the antigravity muscles), while the more vulnerable central cells supply the adductors and flexors, and it is just these muscles which are attacked first and most severely (see *Einarson & Ringsted*, 1938, pp. 72-77 and 117). The same picture has also been produced very clearly by *Erik Krogh* (1944, 1945) by experimental acute anoxia of the lumbar portion of the spinal cord of the rabbit. The anoxia was produced by a specially designed clamp (*Häggqvist*, 1938) by which the aorta was compressed against the ventral surface of the spinal column. By injection of radioactive Na *Krogh* established the fact that a very slow circulation took place in the capillaries in the parts thus occluded, so that it would take an hour or more before the blood in the capillaries would be completely renewed; under normal conditions this renewal lasts less than a minute. Furthermore, injection preparations with India ink gelatin showed that there was no difference between the density of the capillary network in the centre and in the periphery of the anterior horn respectively. The difference in the vulnerability of the peripheral and the central cells of the anterior horn to anoxia is thus not due to a denser or sparser vascu-

larization respectively, but to the position of the cells in relation to the capillary. Krogh made the very important observation that the arteries, even those passing through the centre of the anterior horn, split up into capillaries in the periphery of the anterior horn, while the veins are found in and radiate from the centre. Krogh's explanation of the difference in the vulnerability of the cells is based on this fact. He says, "*The result of the examination of cleared preparations is therefore that the cells in the periphery of the anterior horn are in the main close to the arterial ends of the capillaries, while the central cells lie close to the venous ends. By the very slow circulation produced by the occlusion the peripheral cells will have an opportunity to use up most or all of the oxygen available, and this is the reason why they better resist the lack of oxygen*". (Erik Krogh, 1945, p. 280).

Finally, Krogh discussed the possibility that the greater resistance of the peripheral cells to vitamin E deficiency compared with the central ones, as shown by Einarson & Ringsted, may be due to the same cause. That there may arise a difference in the vitamin E concentration in the arterial and venous ends of the capillaries respectively in spite of the normal rapid circulation, is due to the fact, that vitamin E like all other fat-soluble substances diffuses very easily and quickly through the capillary walls in the central nervous system. It is thus possible that, although the quantities of vitamin E are actually insufficient, the cells in the periphery of the anterior horn may take up any small amounts of vitamin E which may be present in the "vitamin E-free diet", or may still be mobilized from the depots of the animal, and may, therefore, resist the vitamin deficiency better and longer than the cells in the central part of the anterior horn.

It is not only possible, but even reasonable, to assume that the explanation of the varying degree of vulnerability of the anterior horn cells in poliomyelitis is to be found in the conditions discovered by Erik Krogh. Thus it may be surmised that the increased need for oxygen and vitamin E arising during the poliomyelitic process may manifest itself to such

By far the most accurate method of evaluating quantitatively these cellular conditions is, however, staining with gallocyanin-chromalum, since this stain enters into a very selective and stable compound with the polynucleotides of the cells. The photometric estimation of the staining intensity of gallocyanin-chromalum thus gives a measure of the cellular

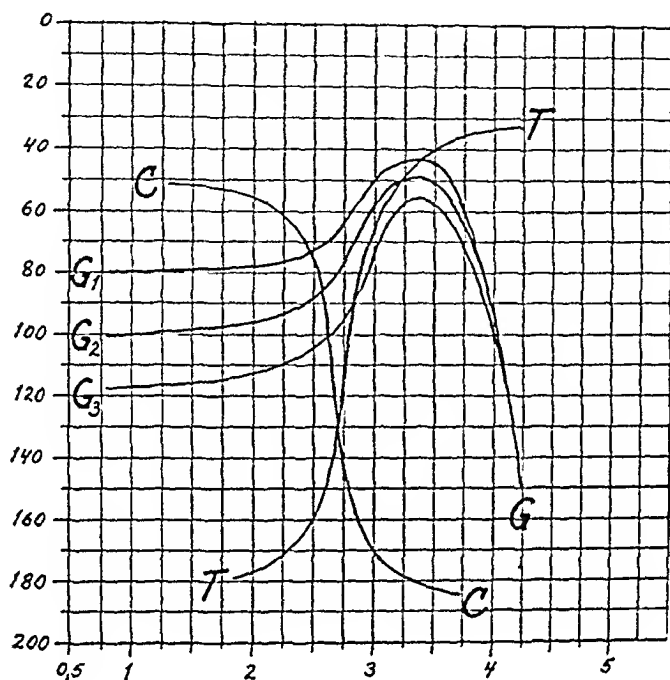


Fig. 3.

T-T and C-C showing the toluidin blue and the cyarol curves for chromonentrality of the nerve cells; the isoelectric point of the Nissl substance lies at pH 2.7. G-G<sub>1</sub>, G-G<sub>2</sub> and G-G<sub>3</sub> representing the gallocyanin curves for extreme chromophily, chromonentrality and extreme chromophoby respectively. See text.

content of nucleic acids, as it may vary, e.g. in vitamin E-deficiency, anoxia and poliomyelitis.

The selectivity of gallocyanin-chromalum staining and its different nature from that of the usual basic blues, can be seen from the intensity curves of the staining; fig. 3 shows also the gallocyanin curves for extreme chromophily, chromonentrality and extreme chromophoby respectively. The slight ascent of the curves from pH 0.8 to pH 2.0, which becomes

steeper from pH 2.0 to pH 2.7, is due to the increasing adsorption of the stain, i.e. the unspecific co-staining of the tissue. This would mean a source of error in the photometric estimation of the intensity of the specific staining if the adsorption were not so slight; at pH 1.64, which is the acidity of the staining solution we usually use, the adsorption is rather negligible and practically unimportant. The intense specific staining in the whole range of pH on the acid side of the isoelectric point *is due to the selective binding of the stain to the polynucleotides of the Nissl substance and the nucleolus, to be explained by the strongly acid properties of the nucleic acids*; here no staining of the proteins can take place (see *Einarson*, 1947, p. 7-9). On the other hand the steep rise of the curves on the alkaline side of the isoelectric point, reaching a peak at pH 3.42, is due to a binding of the stain to the proteins of the Nissl substance in addition to the staining of its polynucleotides (see *Einarson*, 1947, p. 10). The curves fall steeply toward zero from approximately pH 3.6, i.e. the staining fades away; at pH 4.25 it is just perceptible. *The conclusion is that the staining intensity obtained by means of a gallocyanin-chromalum solution, the pH of which lies on the acid side of the isoelectric point of the Nissl substance (e.g. pH 1.64 or less), gives a fairly accurate measure of its content of nucleic acids; most probably the gallocyanin lake-ion<sup>+</sup> become attached to the phosphoric acid groups of the polynucleotides.* (*Einarson*, 1947, p. 13).

The toluidin blue and cyanol curves are typical of staining by electrostatic adsorption. The proteins being amphoteric electrolytes, only combine with cations and positively-charged stains on the alkaline side of the isoelectric point, and with anions and negatively-charged stains only on the acid side. At their isoelectric point the proteins combine with only small amounts of both basic and acid stains.

On the acid side of the isoelectric point of the Nissl substance the gallocyanin lake-ion<sup>+</sup> only combines with the nucleic acids of the cell structures; in the range of pH 0.83-2.7 the binding of the positively-charged stain is independent

of the ionisation of the proteins. *Thus the gallocyanin lake-ion<sup>+</sup> possesses a selective affinity for nucleic acids and it may be characterized and evaluated quantitatively as a histochemical staining reaction.*

#### V. EXTREME CHROMOPHILY AND LIPODYSTROPHY OF THE NERVE CELLS

I have emphasized repeatedly that the state of extreme chromophily of a nerve cell, characterized by the great content of substance stainable with gallocyanin-chromalum, gradually proceeds to irreparable cell atrophy, the final outcome of which is a pale cell shadow from which the Nissl substance has disappeared (e.g. *Einarson, 1949*). Frequently this process is associated with lipodystrophy and vacuolization of the cell (see *Einarson & Lorentzen, 1946*, p. 62-64). As the substance stainable with gallocyanin-chromalum gradually disappears it is replaced by a peculiar, diffuse or densely packed, fatty substance which has a rather dark, greyish-yellow appearance, and sometimes shows a more distinct granular or corpuscular distribution. Undoubtedly we are dealing with a mixture of lipoids, proteins and some lipoproteins, which do not contain nucleic acids; these degeneration products increase simultaneously with the disappearance of the nucleic acids of the Nissl substance.

Finally, the nerve cells may become filled with these lipid and protein substances, which stain intensely with toluidin blue and often with hematoxylin as well, but which are left entirely unstained by gallocyanin-chromalum (see figs. 4 and 5). *This is important since the staining with toluidin blue will simulate extreme chromophily, while gallocyanin-chromalum reveals that this is actually a lipodystrophy of the cell, and very little or nothing of the selectively stainable substance remains (figs. 4 and 5).*

The lipodystrophic change of the nerve cells occurs in the final stage of chronic vitamin E deficiency (fig. 4), in chronic poliomyelitis (fig. 5), as a chronic after effect of partial or

sublethal anoxia and in amyotrophic lateral sclerosis (see *Einarson & Ringsled*, 1938, *Einarson & Lorentzen*, 1946 and *Einarson*, 1949), and like true extreme chromophily is most frequently seen in the human cerebral cortex from various pathological conditions and mental disorders.

In a recent work *Hochberg & Hydén* (1949) studied by ultraviolet microphotography and absorption measurements

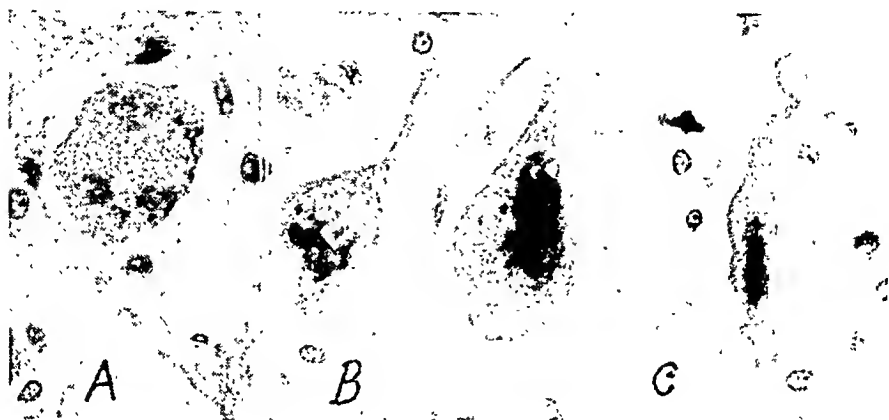


Fig. 4.

Lipodystrophy and irreparable atrophy of spinal motor cells from an adult rat in the final stage of chronic vitamin E deficiency, with severe paralyzes and muscular atrophy. A) The cell is filled with dark lipoid-protein substances; B) cells with still visible remnants of stainable substance; C) a cell showing irreparable atrophy with corkscrew-shaped dendrites.

Gallocyanin-chromalum, pH 1.64.  $\times 550$ .

the motor nerve cells to from rabbits with spastic paralysis produced by occluding the abdominal aorta according to *Häggqvist's* method. They claim that they examined nerve cells, which showed extreme chromophily, and found that they contained no measureable quantities of nucleic acids. On the other hand the physical condition of the cell substance was altered and the intense ultraviolet absorption was caused by the considerable unspecific losses of light due to scattering in the specimen. The authors consider that this result contradicts my interpretation that nerve cells showing extreme



chromophily contain large concentrations of nucleic acids, as evidenced by their intense stainability with galloeyanin-chromalum.

However, there is no doubt that the cells studied by *Hochberg & Hydén* were not in the state of true extreme chromophily, as described by me after staining with galloeyanin-chromalum, *because in pure chromophily of the kind there is*

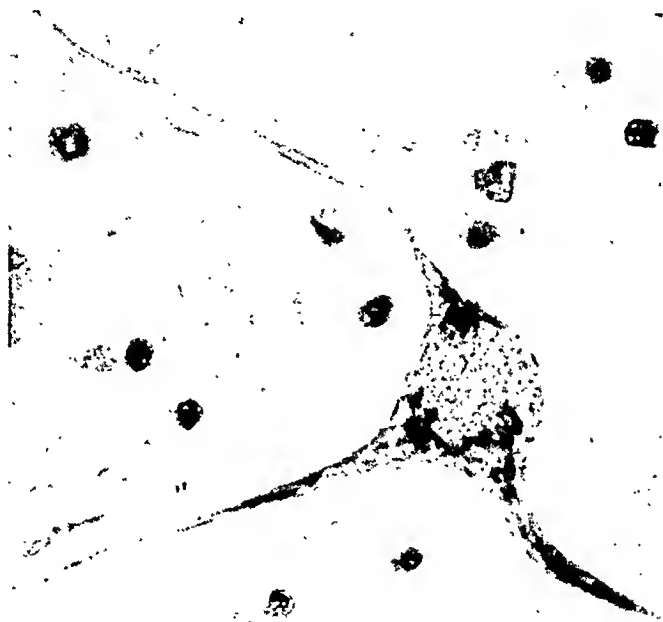


Fig. 5.

Lipodystrophy of a spinal motor cell in chronic poliomyelitis. Some remnants of stainable substance are still visible. Patient died 8 months after the onset of rather severe and widespread paralyses.

Galloyanin-chromalum. pH 1.64.  $\times 600$ .

*never any sign of vacuolization, and the cells of Hochberg & Hydén showed pronounced vacuolization throughout their entire cytoplasm. Vacuolization, lipodystrophy and granular protein degeneration, when following extreme chromophily as secondary changes, first set in at the subsidence or gradual disappearance of true chromophily. On the other hand vacuolization and lipodystrophy are frequently met with as primary changes in or after anoxia.*

Further, *Erik Krogh* (*Acta Jutlandica*. 1945) has con-

clusively demonstrated that true extreme chromophily (gallo-cyanin stain) never occurs as the primary result of acute anoxia as produced by means of the Häggqvist aorta clamp. This particular paper by Krogh is quoted in the list of references of Hochberg & Hydén's paper, but it is not mentioned in their text, although Krogh uses exactly the same occlusion technique as Hochberg & Hydén and Krogh's paper was published 3½ years earlier; otherwise Hochberg & Hydén's paper is very interesting and important. Probably the intense ultraviolet absorption in these dark cells of Hochberg & Hydén, caused by the unspecific losses of light, has been produced by the lipid-protein degeneration substances of the cells, but this condition must not be confused with true extreme chromophily as it appears after staining with gallo-cyanin-chrom-alum.

According to Alsterberg (1948) the lipoids and lipoproteins of the nerve cells which can be stained by his own special JCN-AgC10<sub>3</sub> method are different from the Nissl substance, and are located between the Nissl bodies. After treatment with cold pyridin the Nissl bodies disappear, while the lipid-protein substances are still sharply stained. This is in accordance with my own experience that pyridin, NH<sub>4</sub>OH, NaOH and KOH partly dissolve the Nissl bodies and the nuclear substance, while the surrounding cytoplasm and the karyoplasm stain diffusely with gallamin blue (Einarson, 1935, p. 108-113).

*The conclusion is that I must maintain my interpretation of the state of true extreme chromophily as being tantamount to large concentrations of nucleic acids in the nerve cells. All our work on experimental inhibition, stimulation, anoxia, vitamin E deficiency etc. and observations from human material strongly support the view that the accumulation of nucleic acids in the nerve cells of extreme chromophily is due to a reduced consumption and decomposition of the polynucleotides of the cells and to a defective liberation of adenylic acid. Then ATP is not formed and the ensuing arrest of the synthesis of acetylcholine means an interruption of the impulse transmission of the neurons concerned. Thus the struct-*

*nral state of extreme chromophily of a nerve cell signifies a total cessation of its impulse activity, which may be either temporary or persistent, whether it is produced by chronic, sublethal anoxia, chronic vitamin E deficiency, chronic poliomyelitis or other noxious conditions.*

Important evidence supports the assumption that  $\alpha$ -tocopherol acts by stimulating the liberation of adenylic acid from the polynucleotides of the Nissl substance, and thus  $\alpha$ -tocopherol might possibly help in releasing the nerve cells from their torpid state of extreme chromophily, if it is given before the condition has become irreversible.

#### S U M M A R Y

The Nissl substance of the nerve cells is composed of polynucleotides, acid and basic proteins respectively.

The occurrence of extreme chromophoby of the nerve cells (galloeyanin stain) is due to a reduction or depletion of the polynucleotides of the cells; it corresponds to a state of increased and prolonged physiological activity of the cells (a state of excitation) and represents the initial structural effect of acute anoxia and vitamin E deficiency respectively. It signifies an increased decomposition of the polynucleotides of the cells with an ample liberation of adenylic acid, which is necessary for the constant reformation of ATP, for which there is a great need in the central nervous system owing to the ample consumption and resynthesis of acetylcholine. Structurally, extreme chromophoby closely resembles the initial chromatolysis of acute poliomyelitis.

Extreme chromophily of the nerve cells (galloeyanin stain) is due to an increase or accumulation of polynucleotides in the cells; it signifies a cessation of the physiological impulse activity of the cells (a state of inhibition or totally depressed activity) and represents the late or retarded structural effect of chronic, sublethal anoxia, protracted vitamin E deficiency or chronic poliomyelitis. It is due to a reduced consumption and decomposition of the polynucleotides of the

cells with a consequent defective liberation of adenylic acid; and the ensuing lack of ATP means an arrest of the formation of acetylcholine.

Within a nerve cell the essential source of adenylic acid is the Nissl substance, of which ribonucleic acid (polynucleotides) is a most important component. Thus the liberation of adenylic acid takes place from the cytoplasmic polynucleotides of the nerve cells. Important evidence suggests that vitamin E stimulates this liberation of adenylic acid, which subsequently becomes phosphorylated to form ATP. This phosphorylation may possibly be carried out by acetylphosphate, which at the same time may act as acetyl donor in the synthesis of acetylcholine.

In poliomyelitis the chronic changes of the nerve cells (extreme chromophily, lipodystrophy, irreparable atrophy) may be due to a secondary chronic, sublethal anoxia, to a defective utilization of vitamin E (dysvitaminosis) or to trans-neuronal degeneration. Irrespective of which of the three possibilities plays the most important rôle, and whether vitamin E acts by regulating oxidation or by the occupation of special tissue affinities, it is recommended that the administration of large doses of  $\alpha$ -tocopherol (30-60 mg by mouth daily) to poliomyelitis patients should be tried as a supplementary treatment to the physical training and orthopaedic support of the paretic muscles;  $\alpha$ -tocopherol should perhaps be given in combination with inositol; parenteral administration is less effective.

The greater vulnerability in poliomyelitis of the motor cells located in the central part of the anterior horn as compared with the greater resistance of the cells situated in its periphery, may be due to the circumstance that the peripheral cells lie close to the arterial end of the capillaries, while the central cells lie close to the venous end. If in poliomyelitis the need for oxygen and vitamin E is raised, the amounts available may be consumed at the arterial ends of the capillaries, so that little or none is left for the central cells lying at the venous ends.

In chromoneutral cells the isoelectric point of the Nissl substance lies at pH 2.7; the figure is important for staining. On the acid side of the isoelectric point the gallocyanin lake-ion<sup>+</sup> combines only with the nucleic acids of the cell structures; in the range of pH 0.83-2.7 the binding of the positively-charged stain is independent of the ionisation of the proteins. At an appropriate pH the intensity of the staining with gallocyanin-chromalum gives an accurate measure of the content of nucleic acids in the cell structures; most probably the gallocyanin lake-ion<sup>+</sup> becomes attached to the phosphoric acid groups of the polynucleotides.

Extreme chromophily of a nerve cell may proceed to irreparable atrophy and lipodystrophy, in which the gallocyanin-stainable substance is replaced by lipid-protein degeneration products. The latter stain intensely with toluidin blue and hematoxylin, but are left entirely unstained by gallocyanin-chromalum, which differentiates sharply between the state of true extreme chromophily and the state of lipid-protein dystrophy of a nerve cell. Most probably these lipid-protein substances cause the intense ultraviolet absorption due to scattering and unspecific losses of light in the preparation, but in such cases the dark ultraviolet cell pictures or the toluidin blue pictures must not be confused with true extreme chromophily. At an appropriate pH (1.64 or less) gallocyanin-chromalum gives no unspecific co-staining.

## RESUME

La substance Nissle des cellules nerveuses se compose respectivement de polynucléotides respectivement, de protéines acides et basiques.

Lorsqu'on se trouve en présence d'une chromophilie extrême des cellules nerveuses (coloration à la gallocyanine), c'est qu'il y a réduction ou disparition des polynucléotides des cellules. Ceci correspond à un état d'activité physiologique accrue ou prolongée des cellules (un état d'excitation) et représente l'effet structural initial d'une part de l'anoxie aiguë

et d'autre part d'une déficience en vitamine E. Ceci signifie par ailleurs qu'il y a décomposition accrue des polynueléotides des cellules avec libération appropriée d'acide adénylique nécessaire à la régénération constante de ATP dont il y a un fort besoin dans le système nerveux central par suite de la forte consommation et de la resynthèse de l'acétylcholine. La chromophobie extrême ressemble beaucoup au point de vue structural à la chromatolyse initiale dans la poliomyélite aiguë.

La chromophilie extrême des cellules nerveuses (coloration à la gallocyanine) est due à une augmentation ou une accumulation des polynucléotides dans les cellules; elle indique qu'il y a cessation de l'activité impulsive physiologique des cellules (un état d'inhibition ou d'activité entièrement supprimée) et représente l'effet structural tardif ou retardé soit d'une anoxie chronique sublethale avec déficience de vitamine E, soit de poliomyélite chronique. Elle est due à une consommation réduite et à la décomposition des polynueléotides des cellules avec libération défectueuse d'acide adénylique; le manque d'ATP qui s'ensuit entraîne la cessation de la production d'acétylcholine.

Dans les cellules nerveuses, la substance Nissle est la principale source de production d'acide adénylique et l'acide ribonucléique provient donc des polynueléotides cytoplasmique des cellules nerveuses. Un fait important indique que la vitamine E stimule cette libération d'acide adénylique qui produit ensuite de l'ATP par phosphorylation. Cette phosphorylation est peut-être produite par des acétylphosphate qui peuvent en même temps jouer le rôle de donneur d'acétyle dans la synthèse d'acétylcholine.

Dans la poliomyélite les modifications chronique des cellules nerveuses (extrême chromophilie, lipodystrophie, atrophie irrémédiable) sont dues à une anoxie chronique sublethale secondaire, une utilisation défectueuse des vitamines E (dysvitaminose) ou une dégénération transneurale. Quelle que soit celle de ces trois possibilités qui joue le plus grand rôle et si la vitamine E agit comme régulateur d'oxydation ou possède

certaines affinités de tissu, il est recommandé de donner de fortes doses de  $\alpha$ -tocophérol (30—60 mg par jour et par la voie buccale) aux malades souffrant de poliomyélite comme un traitement complémentaire au traitement physique et orthopédique des muscles paralysés. Il faut peut-être administrer le  $\alpha$ -tocophérol simultanément avec de l'inositol; l'administration parentérale est moins efficace.

La plus grande vulnérabilité dans la poliomyélite des cellules motrices situées dans la partie centrale de la corne antérieure, comparée à la plus grande résistance des cellules de la périphérie est peut-être due au fait que les cellules périphériques sont rapprochées de l'extrémité artérielle des capillaires tandis que les cellules centrales sont rapprochées des extrémités veineuses. Si le besoin d'oxygène et de vitamine E est accru dans la poliomyélite, il est possible que la quantité qui est disponible soit consommée dans l'extrémité artérielle des capillaires et qu'il n'en reste que peu ou point pour les cellules centrales situées autour des extrémités veineuses.

Dans les cellules chromoneutres le point isoélectrique de la substance Nissle est à pH 2,7; sa situation est importante pour la coloration. Du côté acide du point isoélectrique le ion-laque de la galloxyanine + n'est combiné qu'avec les acides nucléiques des structures cellulaires; dans pH = 0,83—2,3 la fixation de la couleur positive est indépendante de la ionisation des protéines. Avec un pH approprié, l'intensité de la coloration au chromalum-galloxyanine donne une indication exacte de la teneur en acides nucléiques de la structure cellulaire; l'ion-laque de la galloxyanine + est plus vraisemblablement fixé aux groupes de l'acide phosphorique des polynuécléotides.

La chromophilie extrême d'une cellule nerveuse peut devenir de l'atrophie irrémédiable et de la lipodystrophie dans laquelle la substance colorable à la galloxyanine est remplacée par des produits de dégénération des protéines lipoïdiques. Ces derniers sont fortement colorés au bleu toluidine et à l'hématoxyline mais sont absolument incolores au chromalum-galloxyanine, ce qui différencie nettement l'état d'extrême

chromophilie véritable et l'état de dystrophie des protéines lipoïdiques d'une cellule nerveuse. Il est très probable que ces substances de protéines lipoïdiques provoquent une absorption ultraviolette intense par suite d'une perte disséminée et non spécifique de la lumière dans la préparation, mais dans ces cas le dessin de la cellule ultraviolette foncée ou celui de la toluidine bleue ne doit pas être confondu avec la chromophilie extrême réelle. Avec un pH approprié (1,64 ou moins), le chromalum-galloyanine ne donne pas de coloration auxiliaire non spécifique.

#### ZUSAMMENFASSUNG

Die Nissl'schen Körperchen der Nervenzellen bestehen aus Polynucleotiden, aus sauren, bezw. basischen Proteinen.

Das Auftreten extremer Chromophobie der Nervenzellen (Gallocyanin-Färbung) ist auf eine Reduktion oder auf den völligen Verlust der Polynucleotide der Zellen zurückzuführen; es entspricht einem Zustande erhöhter oder verlängerter physiologischer Aktivität der Zellen (einem Zustande der Erregung) und stellt die beginnende strukturelle Wirkung einer akuten Anoxie, bezw. eines Vitamin E-Mangels dar. Es ist ein Zeichen vermehrter Zersetzung der Polynucleotide der Zellen mit reichlicher Freisetzung von Adenylsäure, die für die konstante Neubildung des ATP erforderlich ist, für das im Zentralnervensystem infolge starken Verbrauchs und Wiederaufbaus von Acetylcholin ein grosses Bedürfnis vorhanden ist. Die extreme Chromophobie hat strukturell eine grosse Ähnlichkeit mit der anfänglichen Chromatolyse bei akuter Poliomyelitis.

Die extreme Chromophilie der Nervenzellen (Gallocyanin-Färbung) beruht auf einer Vermehrung oder Akkumulation der Polynucleotiden der Zellen; sie ist ein Zeichen dafür, dass die physiologische Impulsaktivität der Zellen aufgehört hat (ein Zustand behinderter oder vollständig unterdrückter Aktivität), und sie stellt die späte oder verzögerte strukturelle Auswirkung einer chronischen, subletalen Anoxie, eines pro-



trahierten E-Vitaminmangels oder einer chronischen Poliomyelitis dar. Sie hat ihre Ursache in reduziertem Verbrauch und Zersetzung der Polynucleotiden der Zellen mit einer defekten Freisetzung von Adenylsäure; und der daraus folgende Mangel an ATP bedeutet ein Aufhören der Acetylcholinbildung.

Die wichtigste Quelle der Adenylsäure in den Nervenzellen sind die Nissl'schen Körperchen, von denen Ribonucleinsäure eine sehr wichtige Komponente ist; die Freisetzung der Adenylsäure geht also von den cytoplasmatischen Polynucleotiden der Nervenzellen aus. Wichtige Tatsachen sprechen dafür, dass das E-Vitamin diese Freisetzung von Adenylsäure stimuliert, die dann durch Phosphorylierung das ATP bildet. Diese Phosphorylierung geht vielleicht mit Hilfe von Acetylphosphat vor sich, das gleichzeitig in der Synthese des Acetylcholins als Acetyl-donor auftreten kann.

Bei Poliomyelitis können die chronischen Veränderungen in den Nervenzellen (extreme Chromophilie, Lipodystrophie, irreparable Atrophie) auf einer sekundären chronischen, subletalen Anoxie, auf einer defekten Ausnutzung des E-Vitamins (Dysvitaminose) oder auf einer transneuronalen Degeneration beruhen. Ohne Rücksicht darauf, welche der drei Möglichkeiten die wichtigste Rolle spielt, und ob die Wirkung des Vitamin E auf einer Regulierung der Oxydation oder auf einer besonderen Gewebsaffinität beruht, empfiehlt es sich, bei Poliomyelitis-Patienten eine Zufuhr von grossen Dosen von  $\alpha$ -Tocopherol (30—60 mg täglich oral) als unterstützende Behandlung der physikalischen Behandlung und orthopädischen Stützbehandlung der gelähmten Muskeln zu versuchen;  $\alpha$ -Tocopherol sollte vielleicht mit Inositol zusammen gegeben werden; eine parenterale Zufuhr ist weniger wirksam.

Bei der Poliomyelitis ist die grössere Empfindlichkeit der motorischen Zellen im zentralen Teil des Vorderhorns im Vergleich mit der grösseren Widerstandskraft der Zellen seiner Peripherie vielleicht auf den Umstand zurückzuführen, dass die peripheren Zellen dicht am arteriellen Ende der Kapillaren liegen, während die zentralen Zellen dicht an den venösen

Enden liegen. Wenn der Bedarf an Sauerstoff und E-Vitamin bei Poliomyelitis vermehrt ist, wird vielleicht die zur Verfügung stehende Menge im arteriellen Ende der Kapillaren verbraucht, weshalb für die zentralen Zellen, die um die venösen Enden herum liegen, nur wenig oder gar nichts mehr übrig bleibt.

In den chromoneutralen Zellen liegt der isoelektrische Punkt für die Nissl'schen Körperchen bei einem pH von 2,7; seine Lage ist für die Färbung von Bedeutung. Auf der sauren Seite des isoelektrischen Punktes verbindet sich das Galloeyanin-Lack-Ion nur mit den Nucleinsäuren der Zellenstruktur; innerhalb eines pH von 0,83—2,7 ist die Bindung des positiv geladenen Farblackes unabhängig von der Ionisation der Proteine. Bei einem entsprechenden pH ergibt die Intensität der Färbung mit Galloeyanin-Chromalum ein genaues Mass für den Gehalt der Zellenstruktur an Nucleinsäuren; das Galloeyanin-Lack-Ion wird aller Wahrscheinlichkeit nach an die Phosphorsäure-Gruppe der Polynucleotiden gebunden.

Die extreme Chromophilie einer Nervenzelle kann bis zur irreparablen Atrophie und Lipodystrophie andauern, bei der die mit Galloeyanin färbbare Substanz von Degenerationsprodukten der Lipide und Lipo-Proteine ersetzt ist. Letztere lassen sich mit Toluidinblau und Hämatoxylin intensiv färben, können aber mit Galloeyanin-Chromalum überhaupt nicht gefärbt werden, was eine scharfe Unterscheidung gestattet zwischen einem Zustande wirklicher extremer Chromophilie und einem Zustande von Lipoid-Protein-Dystrophie einer Nervenzelle. Höchstwahrscheinlich verursachen diese Lipoid-Protein-Substanzen eine intensive ultraviolette Absorption infolge einer Lichtzerstreuung und eines unspezifischen Lichtverlustes in den Präparaten, aber in solchen Fällen darf man die dunklen ultravioletten Zellen-Bilder oder Toluidin-Blau-Bilder nicht mit wirklich extremer Chromophilie verwechseln. Bei einem richtigen pH (1,64 oder darunter) gibt Galloeyanin-Chromalum keine unspezifische Mitfärbung.

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## ON THE TREATMENT OF RADIAL PALSY BY TENDON TRANSPLANTATION

BY

KAJ RØJEL

The treatment of a traumatic radial paralysis which shows no evidence of spontaneous recovery is, in the first instance, operation on the nerve, that is to say, either neurolysis or nerve suture after resection of the scar tissue between the nerve ends.

If these operations are ineffective, or if they cannot be used, either because of the extent of the lesion, or because of complications, e.g. suppuration, there still remains a means of improving the function of the hand, namely, transplantation of the less important flexors of the forearm to some of the paralysed extensors.

The various components of a radial paralysis contribute unequally to the total disability, which is frequently severe.

The palmar flexion and loss of active dorsiflexion, at the wrist, make the hand useless for writing and other finer actions which require either a neutral position or a slight dorsiflexion at the wrist, and also weaken the grip, since the long flexors cannot act with full power.

The adduction and opposition of the thumb can interfere with the flexion of the 2nd and 3rd digits, and the loss of active extension and abduction of the thumb make it difficult or impossible to open the hand for gripping.

The loss of active extension of the metacarpo-phalangeal joints of digits 2-5 also reduces the ability of the hand to open, and of the fingers to assume the position necessary for the action of the long finger flexors. However, this lack of

active extension at the metacarpo-phalangeal joints is partly compensated by the extension of the inter-phalangeal joints by the interossei and the lumbricals.

The pronation position of the forearm is of less importance to the function, both because most of the functions of the hand are performed in pronation, and because the paralysis of the supinator can be partly compensated by the biceps; and many patients learn to supinate the hand and forearm by a special twist.

Similarly, the triceps paralysis is usually of less importance because most of the functions of the hand are carried out below the level of the shoulder, and the absent triceps function can be replaced by the action of gravity in extending the forearm. In addition, the triceps is paralysed in only 10-20 % of radial paralyses (3), which are usually caused by lesions of the nerve distal to the origins of the branches to the triceps.

From this it follows that in transplantation for radial paralysis the chief aims are to obtain dorsiflexion of the wrist, extension of the metacarpo-phalangeal joints of digits 2-5, and abduction and extension of the thumb.

Tendon transplantation for radial paralysis was first performed by *Franke* in 1898 (2); the first transplantation in Scandinavia was performed by *Cappelen* in Norway in 1899 (1). During and after the first world war the operation was much used, especially in Germany, and its value was shown in the works of *Gessner & Riedel* (3), *Perthes* (6), *Mayer* (5) and others.

The various techniques which have been used will not be described in detail here, but their common principles will be discussed. These are:

- 1) Transplantation of the flexor carpi ulnaris to the extensor digitorum communis. This aims to give active dorsiflexion of the wrist and extension of the fingers.

- 2) Transplantation of the flexor carpi radialis or the palmaris longus to the oblique tendons of the thumb. This aims to restore the powers of abduction and extension of the thumb.

3) Arthrodesis of the wrist in dorsiflexion, or

4) Tenodesis of the wrist, one or more of the paralysed extensor tendons being fixed to the bones of the forearm with the wrist in dorsiflexion. By this means palmarflexion is lost, while further dorsiflexion is not prevented.

*Sudeck* (7) recommends suturing the tendons of the extensor digitorum communis to the dorsal carpal ligament with the wrist in dorsiflexion, or joining the extensor tendons together above the wrist, so that the suture site cannot pass under the dorsal carpal ligament. In both cases palmarflexion of the wrist is lost; but the latter method does not prejudice the possibility of active dorsiflexion—in the event of later recovery of the nerve's function or tendon transplantation.

5) Others, including some Americans, have proposed transplanting the pronator teres to the radial extensors of the wrist, in order to give them active function and to reduce the tendency to pronation of the forearm. This method does not seem to have been much used.

The following is the technique used in the Orthopaedic Hospital in Århus:

Through a 15-20 cm. long incision running up from the wrist along the middle of the dorsal surface of the forearm, the bundle of tendons of extensor digitorum communis, and the tendons of extensor pollicis longus, extensor pollicis brevis and abductor pollicis longus are isolated. The tendons of the radial extensors of the wrist are also isolated, if they are to be used for activating the oblique muscles of the thumb, or for tenodesis.

Next, two 15-20 cms. long incisions are made along the ulnar and radial borders of the forearm running proximally from the pisiform and the styloid process of the radius. Through these incisions the flexor carpi ulnaris and flexor carpi radialis are isolated, and later their tendons are divided as far distally as possible.

Muscle fibres of the former arise from the ulna almost down to the wrist-joint, so that it is necessary to cut some of these fibres in order to mobilise a sufficiently long belly.

which should measure 12-14 cms. Isolation of a sufficiently long muscle belly of the flexor carpi radialis presents no similar difficulties.

A blunt instrument is now passed subcutaneously, under the bridges of skin between the three incisions, to make subcutaneous tunnels running from the proximal ends of the two border incisions obliquely distally to the distal end of the middle incision. The two flexors of the wrist are passed through these tunnels, and the border incisions are closed.

With the wrist held in  $40^{\circ}$  dorsiflexion and the fingers extended, the tendon of the flexor carpi ulnaris is passed obliquely distally and radially across the tendons of the extensor communis digitorum and sutured to each one. In the same way the tendon of the flexor carpi radialis is sutured to the tendons of all three, or perhaps only two, of the oblique muscles of the thumb, with the thumb held in abduction and extension. The midline incision is then closed.

When the plaster is removed, between 4 and 5 weeks later, the patient cannot oppose the thumb, nor flex the fingers. These movements are usually quickly recovered with active exercises.

In a number of cases variations of this standard technique have been used, and these will be briefly mentioned here:

In the 6 cases in which the flexor carpi radialis was used for activating the oblique muscles of the thumb (Cases No. 1, 2, 3, 4, 5, 6, and 9) it was in only 2 cases (nos. 4 and 9) transplanted to all three; in the other 4 it was transplanted to only the extensor pollicis longus and abductor pollicis longus.

In 1 case (no. 8) the palmaris longus was used instead of the flexor carpi radialis and it was sutured to the extensor pollicis brevis and the abductor pollicis longus.

In the remaining cases (Nos. 3, 7 and 10), the dorsiflexors of the wrist were not paralysed and the abduction of the thumb was obtained in the following ways: in no. 3 by transplanting the extensor carpi radialis brevis into the extensor pollicis longus; in no. 7 by transplanting one of the radial extensors of the wrist to the extensor pollicis longus and the



other to the abductor pollicis longus; and finally in no. 10 by transplanting the extensor carpi radialis longus into all the oblique muscles of the thumb.

In these last 3 cases it was possible to transplant to the oblique muscles of the thumb through the dorsal incision, so that it was not necessary to make the radial incision.

In all 10 cases the transplantation to the extensor digitorum communis was by the method already mentioned, using the flexor carpi ulnaris.

Finally, tenodesis of the wrist was done in nos. 1 and 2, using the tendon of one of the radial extensors of the wrist, first cutting it and then suturing it to the periosteum on the dorsal surface of the radius.

This material from the Orthopaedic Hospital in Århus consists of 10 patients, who, since 1937, have been operated on by the method described above. Their case histories and follow-up examinations will be briefly described here.

*No. 1. J. 1883.* A girl aged 15 years. 5 years previously a blow on the L. arm without fracture. Typical complete isolated paralysis of the radial nerve below the branches to the triceps. Operation 13.7.37, 5 years after the paralysis: 1) flexor carpi ulnaris to extensor digitorum communis, 2) flexor carpi radialis to extensor pollicis longus and abductor pollicis longus, 3) tenodesis. Follow-up, 11 years after operation: 20° ulnar deviation of the wrist. Active movements of the wrist with clenched hand: 30° dorsiflexion, 80° palmarflexion, with extended fingers: 5° dorsiflexion, 50° palmarflexion. The transplanted flexor carpi ulnaris and the site of the suture between it and the extensor communis digitorum, henceforth called only "suture site", cannot be felt. Digits 2-5 have normal active and passive movements of all joints, and the hand is clenched normally. The hand grip is weak. No excursion registered on the dynamometer, and the wrist goes into 80° plantarflexion and 30° ulnar deviation, but if the hand is supported in slight dorsiflexion 10 kg. can be registered. No difference between the sound and operated sides with "finger crooking". The thumb: abduction 40°, flexion 35°, extension — 20° (i.e. the carpo-metacarpal joint lacks 20° of extension in the same plane as the fingers), normal flexion and extension in the metacarpophalangeal and interphalangeal joints, normal opposition with the tip against the root of the little finger. At this examination the patient was aged 26 years, married, looked after her home and in addition had a sewing establishment where she worked without any difficulty. She was

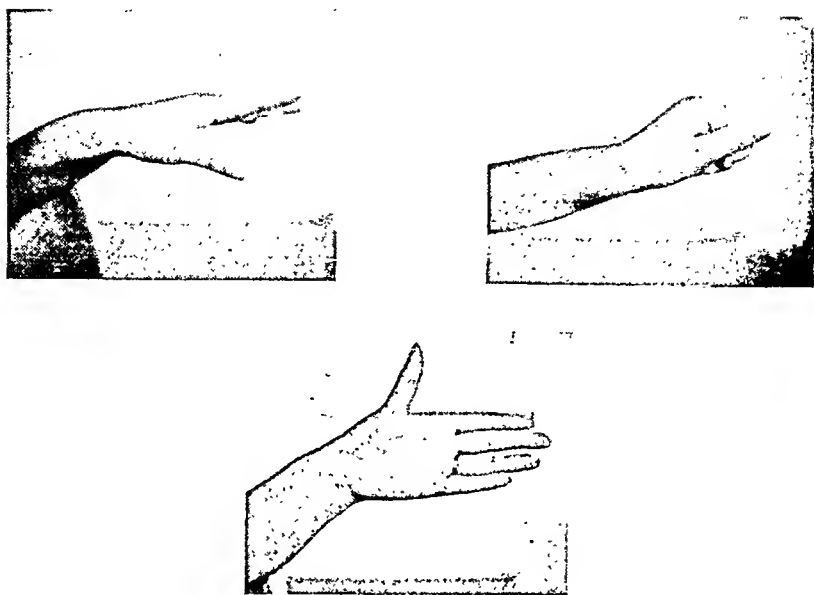


Fig. 1.

well satisfied with the results of the operation. No. 1 photographed 22.6.48.

No. 2, J. 2155. (1937). Boy, aged 15 years. Typical complete isolated radial paralysis below the branches to the triceps after operation for osteomyelitis of the R. humerus a year previously. Sequestrum discharged while in this hospital. Operation 9.8.47. 1 year after the paralysis: 1) flexor carpi ulnaris to extensor communis digitorum and extensor indicis; 2) flexor carpi radialis to extensor pollicis longus and abductor pollicis longus; 3) tenodesics of the wrist. Follow-up 11 years after operation: Marked atrophy of the muscles on the dorsal and radial sides of the forearm. Active movements in the wrist with fist clenched:  $45^{\circ}$  d.f./ $50^{\circ}$  p.f., and with extended fingers:  $20^{\circ}$  d.f./ $80^{\circ}$  p.f. Definite contraction of flexor carpi ulnaris and movement of the suture site. No side deviation at the wrist. Normal active movements in all joints of digits 2-5. The hand is clenched normally. Power on the dynamometer 1 kg., the hand going into  $80^{\circ}$  palmarflexion. If the hand is supported in slight dorsiflexion the power is 12 kg. No difference of "finger-crooking" power between the two hands. The thumb: carpo-metacarpal joint has  $30^{\circ}$  abduction,  $45^{\circ}$  flexion,  $\div 10^{\circ}$  extension, and normal opposition, with the tip of the finger against the root of the little finger. Normal active movement in the metacarpo-phalangeal and interphalangeal joints. The patient is a builder's carpenter and manages all the work involved without any difficulty. He is well-pleased with the result of the operation. No. 2 photographed 21.7.48.

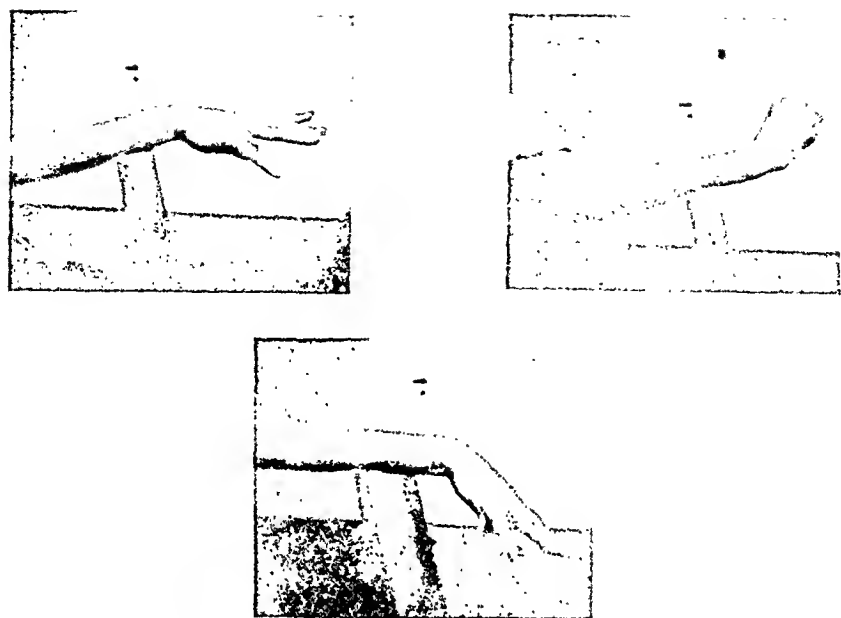


Fig. 2.

No. 3, *J.* 10372, (1941). Boy, aged 12 years. Injured 5 months previously in the belt of a threshing-machine. Multiple fractures of the R. arm, with a Volkmann's paralysis, which made the limb almost useless. Fracture of the L. forearm with paralysis of extensor communis digitorum and of the oblique muscles of the thumb, with preservation of the dorsiflexors of the wrist; corresponds to a lesion of the posterior interosseous branch of the radial nerve. Operation 1.3.41. 6 months after the injury: 1) flexor carpi ulnaris to extensor digitorum communis; 2) extensor carpi radialis brevis to extensor pollicis longus. The latter was not divided since the possibility of reinnervation could not be excluded. Follow-up 7 years after operation: No side deviation of the wrist of which the active movements with clenched fist are  $60^{\circ}$  d.f./ $50^{\circ}$  p.f., and, with extended fingers,  $30^{\circ}$  d.f./ $75^{\circ}$  p.f. Dynamometer: 52 kg. Normal movement of all digits including the thumb. It was specially noted that tightening of the tendons of extensor pollicis brevis and abductor pollicis longus on abduction suggested activity of these muscles. These 2 muscles were not activated at operation, so they must have been re-innervated post-operatively. This case, in which the hand is by all criteria normal, must therefore be excluded from the operation results.

No. 4, *J.* 13165, (1912). Man aged 45 years. Typical, complete, isolated paralysis of the radial nerve distal to the triceps branches after a blow on the arm, without fracture, 11 months previously. Operation: 7.9.12. 13 months after the injury, and 7 months after neurolysis without result: 1) flexor carpi ulnaris to extensor digitorum communis; 2) flexor carpi

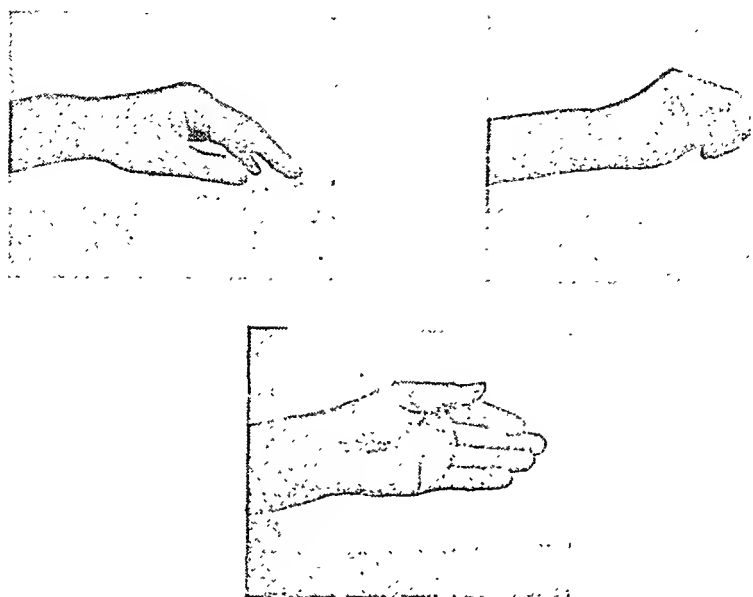


Fig. 4.

radialis to the 3 oblique muscles of the thumb. Follow-up 6 years after transplantation: No side deviation of the wrist. Active wrist movements with clenched fist:  $70^{\circ}$  d.f./ $15^{\circ}$  p.f., and with extended fingers  $70^{\circ}$  d.f./ $0^{\circ}$  p.f. Visible contraction of the flexor carpi ulnaris and movement of the suture site can be felt. The meta-carpophalangeal joints of digits 2-5 are held in the following positions and cannot be actively straightened:  $120^{\circ}$ ,  $130^{\circ}$ ,  $120^{\circ}$  and  $90^{\circ}$ ; active flexion to  $90^{\circ}$ ,  $100^{\circ}$ ,  $90^{\circ}$  and  $70^{\circ}$ . There is full passive movement of these joints, so restriction of active movement by capsular contracture can be excluded. Normal active movement of the interphalangeal joints of these digits. The hand is clenched normally. The patient has some difficulty in grasping the dynamometer, but when he has done so, without the help of the sound hand, he registers 25 kg. (Sound hand 30 kg.). Same power in the 2 hands with finger-crooking. The thumb: Carpo-metacarpal joint: abduction  $20^{\circ}$  with simultaneous flexion to  $30^{\circ}$ , flexion  $40^{\circ}$ , extension  $\div 30^{\circ}$ , opposition with the tip against the root of the 4th finger. Normal movements of the meta-carpophalangeal and interphalangeal joints. The patient is a labourer and can do all his work. He has slight difficulty with taking hold of things, e.g. the handle of a shovel, but when he has got hold of it correctly his grip is good and strong. He is very pleased with the result of the operation. Case 4, photographed 19.10.42.

No. 5. J. 15111. (1942). Following a coramine injection in the R. forearm 19 months previously, paralysis of the extensor digitorum communis and the oblique muscles of the thumb, but preservation of active

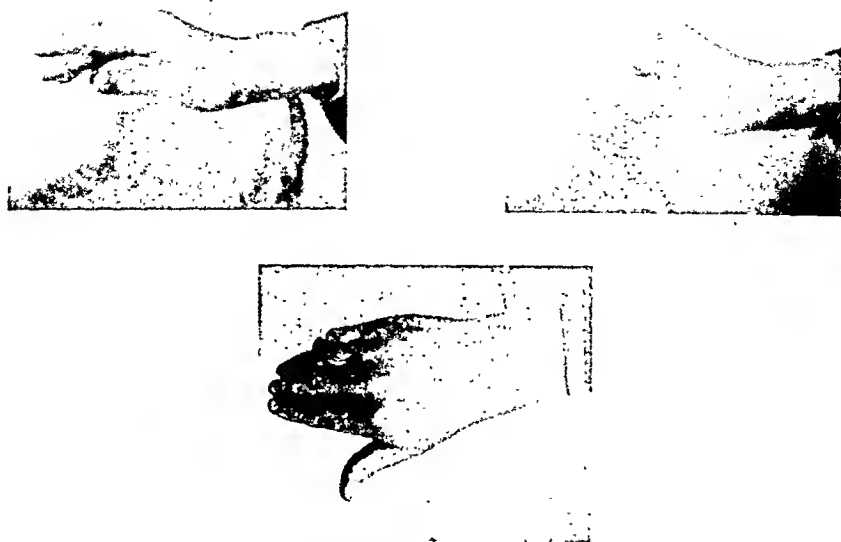
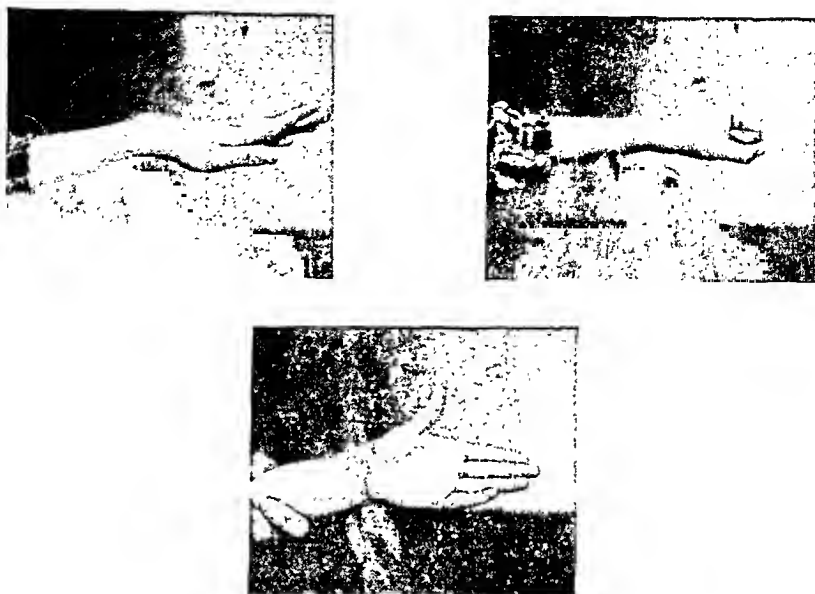


Fig. 5.

dorsiflexion of the wrist. Operation 11.9.42. 19 months after the paralysis: 1) flexor carpi ulnaris to extensor digitorum communis; 2) flexor carpi radialis to extensor pollicis longus and abductor pollicis longus. Follow-up 6 years after operation: Active movement of the wrist with clenched fist:  $60^\circ$  d.f./ $25^\circ$  d.f., and with extended fingers:  $60^\circ$  d.f./ $5^\circ$  d.f. The suture site could be felt to be mobile. Active movement of metacarpophalangeal joints of digits 2-5:  $150-110^\circ$ , normal active movement of interphalangeal joints. Normal fist. Dynamometer pressure 30 kg. (Sound hand 32 kg.). Equal power of the two hands with finger-crooking. The thumb: Carpo-metacarpal joint movements: abduction  $30^\circ$ , flexion  $30^\circ$ , extension  $\pm 20^\circ$ , opposition with tip of thumb to root of the 4th digital space. Normal movements of the metacarpophalangeal and interphalangeal joints. The patient now works only in an office; he writes without difficulty. Previously he worked as an egg packer and could also do this without difficulty. He is very pleased with the result of the operation. Case No. 5, photographed 15.9.43.

No. 6, J. 15524. (1942). Boy, aged 8 years. Extensive laceration of the arm in a road accident 14 months previously. Complete, typical, isolated, radial paralysis distal to the triceps branches. Operation 21.12.42. 15 months after the injury: 1) flexor carpi ulnaris to extensor digitorum communis; 2) flexor carpi radialis to extensor pollicis longus and abductor pollicis longus. Follow-up 5½ years after operation: Active movements in the wrist with clenched fist:  $40^\circ$  d.f./ $60^\circ$  p.f., and with fingers extended:  $5^\circ$  d.f./ $70^\circ$  p.f. Active contraction of flexor carpi ulnaris is

*Fig. 6.*

felt, with movement of the suture site. Completely normal active movement of all joints of digits 2-5. The hand is clenched normally. Weak power: dynamometry 0 kg., and the hand goes into  $70^{\circ}$  palmarflexion and  $30^{\circ}$  ulnar deviation. With the hand supported in slight dorsiflexion the dynamometer records 10 kg. (Sound hand 15 kg.). Equal power in the two hands with finger-crooking. The thumb: completely normal active and passive movements in the carpo-metacarpal, metacarpo-phalangeal and interphalangeal joints. The patient is employed as a boy on a farm and says he can do everything, including milking. Case No. 6. photographed 15.11.43.

No. 8. J. 23156. (1944). Man, aged 23 years. He developed L. radial paralysis distal to the triceps branches 13 months previously, after spraying fruit trees with lead arsenate. Medical treatment had no result. Since he had had a fracture in the elbow region 11 years previously which had left some weakness of the arm the nerve was explored in the neurosurgical department. This operation also had no result. Operation 2.5.45. 21 months after paralysis: 1) flexor carpi ulnaris to extensor digitorum communis; 2) palmaris longus to abductor pollicis longus and extensor pollicis brevis. Follow-up 3 years after operation: The transplanted flexor carpi ulnaris has changed into a firm fibrous cord without active contraction, and the suture site can be felt firmly fixed during the movements of the wrist. Both the wrist and the metacarpo-phalangeal joints of digits 2-5 can be moved actively, but only in such a way that movement at one at once produces a contrary movement at the other, and

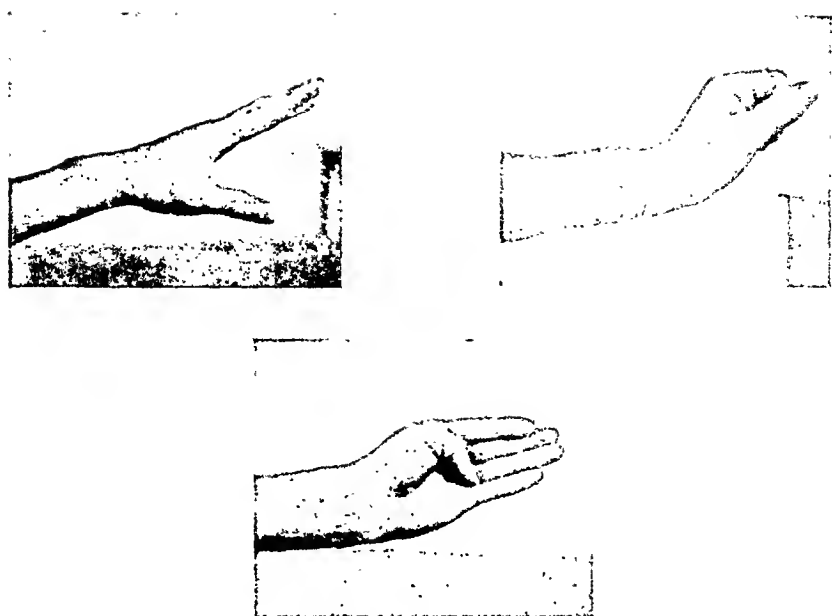


Fig. 8.

isolated active movement of the wrist or the fingers is not possible. When the hand is clenched the wrist goes into  $35^\circ$  dorsiflexion; but this position can only be taken up when the hand is clenched and as long as it is clenched, the wrist can not be moved either actively or passively. When the fingers are extended the wrist flexes to  $0^\circ$ , and remains there so long as the digits remain in this position. These two movements, extension of the fingers and palmar flexion of the wrist, are inseparable, so that one can only be done with the other. The active movements of the metacarpo-phalangeal joints of the fingers are normal with the above reservation, and there is normal movement at the interphalangeal joints. The dynamometer pressure is 16 kg. There is equal power on the 2 sides with finger-crooking. The hand is clenched normally. The thumb's carpo-metacarpal joint: abduction  $30^\circ$  (with simultaneous  $30^\circ$  flexion), flexion  $35^\circ$ , extension  $\div 25^\circ$ , opposition normal with the tip of the thumb opposite the root of the 5th finger. Metacarpo-phalangeal and interphalangeal joints normal active movements. The patient is a postman and has no trouble at his work. Case No. 8, photographed 29.6.48.

No. 9, J. 34108, (1946). Man, aged 23 years. Fracture of the lateral condyle of the humerus 6 months previously, with paralysis of the radial nerve below the branches to triceps. Operation 7.10.46. 6 months after the paralysis. Beck's drilling for psendarthrosis, and tendon transplantation: 1) flexor carpi ulnaris to extensor digitorum communis; 2) flexor carpi radialis to all the oblique muscles of the thumb. Follow-up 2 years after operation: No side deviation at the wrist, which, with the fist



Fig. 9.

clenched, has 75° d.f. and 20° p.f., and with the digits extended as far as possible, 80° d.f./35° p.f.: contraction of flexor carpi ulnaris and movement of the suture site is felt. Digits 2-5 are held in 90° flexion at the metacarpo-phalangeal joints and cannot be actively extended; passive extension is normal. There is normal active movement of the interphalangeal joints. Normal fist-clenching. Dynamometer pressure 10 kg., during which the wrist is flexed to 20°. (Dynamometer pressure of sound hand is 44 kg.). The thumb is abducted, flexed and extended normally; its tip is opposed to the side of the base of the 4th finger. Normal movements of the interphalangeal joints. The patient is fairly satisfied with the result of the operation. He is a country postman and can use the hand well for coarser movements, e.g. holding the bundles of letters, but it is awkward for finer movements. Case No. 9, photographed 10.12.46.

No. 10. J. 40365. (1947). Man, aged 21 years. Puncture lesion of the L. cubital region 3 months earlier, with paralysis of the extensor digitorum communis and the oblique muscles of the thumb, and preservation of dorsiflexion of the wrist. Operation 13.11.47, 3 months after the injury: 1) flexor carpi ulnaris to extensor digitorum communis; 2) extensor carpi radialis longus to the oblique muscles of the thumb. Follow-up 6 months after operation: Active movement of the wrist with fist clenched: 40° d.f./25° d.f., and with extended fingers 60° d.f./5° p.f. during which active contraction of the flexor carpi ulnaris and movement of the suture site can be felt. Active movement of the metacarpo-phalangeal joints of digits 2-5 is 180°/120°, and movements of the other joints are normal. Clenching the fist is practically speaking normal, apart from defective flexion in the metacarpo-phalangeal joints which makes the finger tips reach rather more distally than normally. Dynamometer pressure 15 kg. (Sound hand 30 kg.). Equal power of the two hands with finger-crooking. The thumb: carpo-metocarpal joint: abduction 45°, flexion 45°, extension ÷ 20°, opposition with the tip against the base of the 4th digital space. Normal movement in the metacarpo-phalangeal and interphalangeal joints. The patient is a labourer in the country and can do all work, including milking with a little difficulty. Case No. 10, photographed 25.2.48.



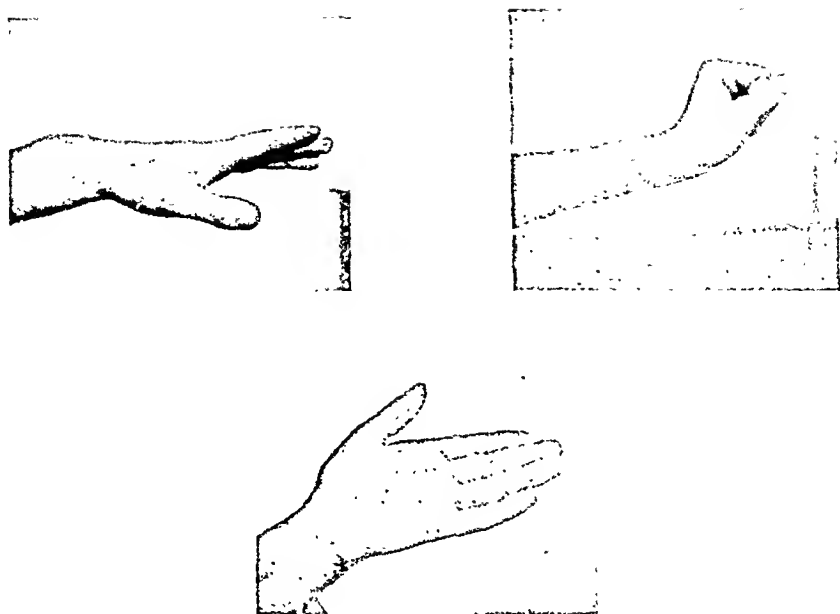


Fig. 10.

## DISCUSSION

*The indications for operation, and the possibility of post-operative recovery of the nerve function.* The indications for tendon transplantation were quite clear in cases nos. 1, 2, 4, 5, 6 and 8; the interval after the occurrence of the paralysis was 1 to 5 years without any sign of spontaneous improvement. Operation on the injured nerve was also contraindicated in nos. 2 and 6 for local reasons, osteomyelitis in the former, and extensive scarring in the latter. In 2 other cases, nos. 4 and 8, the nerve had been operated earlier without result.

In these cases it is evident that recovery of the nerve's function could not have occurred after the transplantation, and it must be accepted that the good results were due to the transplantation, and not to later reinnervation.

This is not the case with the remaining 3 cases, nos. 3, 9 and 10. Case no. 9 had a tendon transplantation 6 months after the injury as the Beck's drilling for pseudarthrosis was done at that time, and cases nos. 3 and 10, in which the signs pointed to a lesion of the posterior interosseous nerve, were operated on respectively 6 and 3 months after the injury.

In view of the good results of tendon transplantation, which may probably be compared with those after operation on the nerve, and of the probable reduction in contractures and disuse atrophy of the non-paralysed muscles with early tendon transplantation, the wider indications by which the last 3 cases were operated cannot be condemned, although spontaneous recovery of the nerve's function could not be excluded at the time of operation.

In these 3 cases the theoretical possibility of reinnervation after the tendon operations makes it impossible to assess the results of the operation. Evidence of postoperative regeneration was found in case no. 3, as already described, and this patient has been excluded. In cases nos. 9 and 10 the results were the same, or a little less good, than those found in the other cases, so that little falsification results from their inclusion included in the assessment of the results of the tendon transplantations.

*Follow-up examinations.* Table 1 shows the results of follow-up examination of the wrist and digits 2-5. The down columns show the patients, first the 6 with radial paralyses, and then the 3 with posterior interosseous paralyses. The horizontal rows show the most important examinations.

The active movements of the wrist with, respectively, flexed and, as far as possible, extended fingers, is shown in the two first horizontal rows with a Y-shaped figure, whose stem corresponds with the forearm, and whose arms show the range of movements at the wrist. The stippled horizontal line gives the neutral position between dorsiflexion above and palmarflexion below. The figures on the arms of the Y show the degrees of deviation from 0°.

The active movement of the metacarpo-phalangeal joints is similarly shown in the 3rd horizontal row by a T-shaped figure, of which the left arm represents the line of the mid-hand, and the right arm and the stem the proximal phalanx in extension and flexion respectively. The figures on the right arm and the stem give the angles made by the basal phalanx with the palm in maximum extension and flexion. The normal

TABLE 1.

		TRUE RADIAL NERVE PARALYSIS						POSTERIOR INTEROSSEOUS NERVE PARALYSIS		
		1	2	4	6	8	10	3	5	10
RANGE OF ACTIVE MOVEMENT OF THE WRIST WITH CLENCHED HAND	D									
	P									
RANGE OF ACTIVE MOVEMENT OF THE WRIST WITH MAXIMAL EXTENSION OF THE FINGERS	D									
	P									
RANGE OF ACTIVE MOVEMENT OF THE METACARPO-PHALANGEAL JOINTS	D									
	P									
RANGE OF ACTIVE MOVEMENT OF THE OTHER FINGERJOINTS		NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL
FIST-CLENCHING		NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL
DYNAMOMETER PRESSURE IN FG. (POWER OF SOUND HAND IN BRACKET)		0	2	26(30)	0(15)	16	16(44)	52	30	15(30)
PALMARFLEXION OF WRIST DURING DYNAMOMETRY		80	80		70		20			
DYNAMOMETER PRESSURE WITH THE WRIST SUPPORTED		10	12		10					
POWER WITH "FINGER-CROOKING"		NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL

position of extension at the metacarpo-phalangeal joints is thus represented as  $180^\circ$ .

The 3 next horizontal rows require no further explanation than that given in the Table. Under the heading "Palmar flexion of the wrist during the dynamometer test" the angle of forced palmarflexion of the wrist during the test is shown in the way already described. A O indicates that the wrist was not flexed beyond the neutral position.

The last but one horizontal row shows power recorded by the dynamometer in cases where the power was increased by supporting the wrist.

The last horizontal row shows the "crooked finger" power, which will be explained later.

For the function of the thumb, reference should be made to the case histories since it seemed unnecessary to present it in a table.

*The Material.* Tendon transplantation for radial paralysis has been done in 10 cases since the Hospital was opened. In case no. 8 the paralysis was presumably of toxic origin; in the others it was caused by various traumata. One patient, no. 7, could not be re-examined, and one patient, no. 3, has had to be excluded because of post-operative reinnervation, as al-

ready described. The cases can be divided into 2 groups. In nos. 1, 2, 4, 6, 8 and 9 all of the muscles innervated by the radial nerve in the forearm were paralysed, including the extensors of the wrist. In 5 of these cases, that is, all but no. 8, both the history and examination pointed to a lesion of the arm as the cause of the damage to the nerve. For this group I have not been able to find any better description than "true radial paralysis".

The remaining 2 cases, nos. 5 and 10, and the excluded no. 3, showed only paralysis of extensor digitorum communis and the oblique muscles of the thumb, with preservation of the function of the radial extensors of the wrist, and therefore of active dorsiflexion of the wrist. These lesions, which correspond to damage of the posterior interosseous nerve are grouped under the term "paralysis of the posterior interosseous". In all the cases the triceps' function was intact.

The follow-up findings will now be presented in cross-section, each function being studied for all the cases.

*Movements of the Wrist.* Tenodesis was done in cases nos. 1 and 2, and was without effect, since marked palmarflexion of the wrist occurred in both.

All patients showed active dorsi- and palmarflexion at the wrist.

In patient no. 8 a peculiar arrangement occurred, as already described in his case history. The transplanted flexor carpi ulnaris was converted into an inactive fibrous cord, the suture site was fixed, and the movements of the wrist were coupled with contrary "compensatory" movements in the metacarpo-phalangeal joints. Since no active extensors of either the wrist or the metacarpo-phalangeal joints could be found, their active extension could be explained only as an action of the flexors of the digits, possibly in conjunction with the action of the active flexor carpi radialis. Evidently the operation had resulted in a tenodesis of the tendons of the extensors of the digits above the wrist, as is done in Sudeck's operation. Their length from the suture site to their insertion

was constant. When the fist was clenched the part of the tendons which lay on the fingers lengthened; this was only possible if there was a corresponding shortening of the tendons between the metacarpo-phalangeal joints and the suture site; this forced the wrist into dorsiflexion. The same mechanism extended the metacarpo-phalangeal joints, when the wrist was actively palmar-flexed.

The rest of the cases all showed active dorsiflexion of the wrist, with the fingers both tightly flexed, and extended as straight as possible. The interest is here in the other 5 patients (cases nos. 1, 2, 4, 6 and 9) with true radial paralysis, in whom the dorsiflexors of the wrist were paralysed before operation. In them the restoration of active dorsiflexion of the wrist must be due to the action of the transplanted flexor carpi ulnaris, and in several one could feel the active contraction of this muscle and the movement of the suture site.

The range of movement in relation to the neutral position is shown in the two upper rows of the Table. It shows that there were big variations, but the cases can be divided into two well-defined groups.

*Group A* consists of cases nos. 4, 5, 9 and 10, in whom the palmarflexion was limited to near the neutral position. Case no. 8, whose condition has been discussed above, must be included with these.

Two causes for this reduced palmarflexion were demonstrated by case 8, namely 1) fixation of the suture site, and/or 2) conversion of the transplanted muscle into a fibrous band. These 2 causes do not apply to cases 4, 9, 5 and 10, in whom both the muscle was active and the suture site mobile. In these cases one might think 3) that the transplanted muscle by active contraction prevented palmarflexion of the wrist. This idea must, however, be rejected for two reasons, firstly because it does not explain how, as has been described below, the transplanted muscle then fails to hinder the strong compulsory palmarflexion in the patients in *Group B*, when these contract their finger flexors maximally, and secondly because it seems unlikely that this muscle whose power is said to

be 5 kg. (7) should be able to equal the strong pull of the flexors of the forearm.

I think that the most likely explanation of the reduced palmarflexion is 4) that the suture site lies so far distally on the extensors that it is stopped by the dorsal carpal ligament and the partitions under this ligament, so that palmarflexion is prevented.

*Group B* includes the rest of the cases: (nos. 1, 2 and 6). Here there is good range of all movements at the wrist. Since it is clear that the suture site cannot pass through the partitions under the dorsal carpal ligament, one must assume that in these cases this site lies so far proximally on the extensors that it either does not at all, or only with strong palmarflexion, come up against the upper border of the dorsal carpal ligament.

*Movements of Digits 2-5.* In cases nos. 1, 2 and 6 there was normal movement at the metacarpo-phalangeal joints, and in nos. 5 and 10 there was slight but functionally unimportant reduction in the range of movement; the movement of these joints was not affected by the position of the wrist in these cases. Thus the results of the transplantation were in these cases good or satisfactory as far as the active extension of these joints was concerned. Case no. 8 also showed normal active movement of these joints; the particular condition in this case has already been discussed.

Reduction of the range of movement in the metacarpo-phalangeal joints, severe enough to impair the function of the hand, was seen in only 2 cases (nos. 4 and 9) in which the joints were held in marked or maximal palmarflexion and showed little or no active dorsiflexion. In both cases there was good contraction of the transplanted flexor carpi ulnaris, which acted, however, mainly, or exclusively on the wrist, and only slightly or not at all on the fingers. The reason for this is not clear to me.

The movements at the interphalangeal joints were normal, and clenching the fist normal or nearly normal in all the patients.

*Dynamometry.* The cases divided into the same 2 groups with dynamometry as with flexion of the wrist:

In Group A are cases nos. 4, 8, 9, 5 and 10, in whom the palmarflexion of the wrist was limited; dynamometry showed good or fairly good power. In cases 4 and 5 the power of the operated hand nearly equalled that of the sound hand. The rest of the patients in this group showed powers varying between 25 and 50 % of that of the sound hand—but still quite good power.

In Group B are cases nos. 1, 2 and 6, in which the palmarflexion of the wrist was good; dynamometry showed either 0 or minimal power; the wrist went into maximal palmarflexion at the same time as pressure on the dynamometer was attempted.

The "crooked finger" power was tested by the following method: the examiner and the patient held their metacarpophalangeal joints extended and their interphalangeal joints acutely flexed, and hooked their fingers together homolaterally: by pulling the examiner could compare the power with which the patient flexed the fingers of the operated hand with that of the sound hand. This power depends solely on the flexors of the digits and is not affected, like the dynamometer test, by instability of the wrist. Thus the power of the crooked fingers was a more direct indication of the power of the flexors of the digits than dynamometry.

I found no difference in the crooked finger power between the sound and the operated hands, in any of the patients. Thus the reduced power registered on the dynamometer did not represent a reduction in the power of the flexors of the fingers.

When dynamometry was carried out with the wrist supported, so that the forced palmarflexion was prevented, the patients of Group B registered powers of the same order as those of Group A.

The difference in the dynamometer powers of the two groups was obviously related to the different palmarflexions at the wrist. In Group A, either the suture site was fixed, or

it was blocked by the dorsal carpal ligament, so that palmar-flexion was stopped before it could interfere with the maximal power of the flexors of the fingers. The cases in Group B had no such braking mechanism, and since the transplanted flexor carpi ulnaris could not overcome the power of the strong flexors, the wrist was pulled into palmarflexion, whereby the flexors of the digits in their turn lost their full power.

The reduction of dynamometer power in the operated hands in Group A, compared with the sound hands, in spite of no difference in the power of the flexors when the power of the crooked fingers was tested, may perhaps be explained by some of the flexors' power being used to resist the extensors, so that there was a corresponding reduction in their flexing power.

*Movements of the Thumb.* In all cases the activation of the thumb's abductor had a good result. In most patients the abduction of the thumb was normal or, since it was at the same time slightly flexed, nearly normal. Nearly all the patients had 20° to 30° limitation of extension at the carpometacarpal joint, but this did not interfere with function. In all cases, opposition was normal or nearly normal.

### CONCLUSION

A comparison of the results of operation in the two groups, A and B, shows that the former has the advantage. The patients of Group A have a strong grip of their working tools, etc., and the reduced movement at the wrist is unimportant. It must be mentioned that the 2 patients who have loss of extension of the metacarpo-phalangeal joints which interferes with function, belong to this group, but there is no obvious causal relation between this loss of extension and the reduced palmarflexion of the wrist. The good palmarflexion of the wrist in the cases of Group B is of no advantage, and the weakened power of the hand is a disadvantage.

Thus the conclusion to which the study leads us is that at operation one must aim to produce a restricting arrange-



ment to limit palmarflexion of the wrist. Probably it will be best to do a tenodesis using the paralysed extensors of the wrist. Since cases nos. 1 and 2 have shown that suture of the tendons to the periosteum of the forearm bones does not hold, the method recommended by *Pertthes* (6), in which the tendons are passed through bore-holes made in the bones, and fixed on the opposite side should be used. If one does not wish to do a tenodesis, the suture site, where the tendon of the flexor carpi ulnaris is sutured to the tendons of extensor digitorum communis, should be as far distal as possible, so that the suture site will prevent marked palmarflexion of the wrist as it comes up against the dorsal carpal ligament.

#### SUMMARY

The method used for tendon transplantation in cases of radial paralysis at the Orthopaedic Hospital in Århus is described. The flexor carpi ulnaris is transplanted to the extensor communis digitorum, and abduction and extension of the thumb is obtained by transplantation of flexor carpi radialis or, in some cases of palmaris longus, to its oblique muscles. In cases in which the extensors of the wrist are not paralysed, these can be used to extend and abduct the thumb.

The material consists of 8 patients. 2 of them had paralysis of the extensor digitorum communis and oblique muscles of the thumb, with preservation of the function of the extensors of the wrist. These have been termed "posterior interosseous paralyses". The 6 remaining cases all had paralyses of all the muscles innervated by the radial nerve in the forearm. They have been termed "radial paralyses".

The findings at the follow-up examinations are shown in Table 1. Case 8 had no action in the transplanted flexor carpi ulnaris, and in this patient the active movements at the wrist and metacarpal joints were assumed to be by the flexors of the fingers. All the other patients had good function of the transplanted flexor carpi ulnaris.

Patients nos. 4 and 9 lacked active extension at the meta-

carpo-phalangeal joints, which impaired the function of the hand. In the other patients active movements of the meta-carpo-phalangeal joints were normal, or nearly normal. All the patients had normal movements of the interphalangeal joints, and could make a normal, or nearly normal, fist.

If the movement at the wrist and the power of the hand is considered the cases fall into 2 groups: *Group A* contains patients nos. 4, 8, 9, 5 and 10, who all showed good power when tested with a dynamometer, and limitation of palmarflexion at the wrist, probably because the suture site between the flexor carpi ulnaris and the extensor communis digitorum was so far distal on the extensor tendons that its movement was restricted by the dorsal carpal ligament. *Group B* contained patients nos. 1, 2 and 6, who showed good palmarflexion of the wrist and minimal power on dynamometry, the wrist being forced into palmarflexion.

Movements of the thumb were nearly normal, and, from the functional point of view, wholly satisfactory.

The operation results have on the whole been good, and the patients have generally been well satisfied. It is possible that the results can be improved if one tries to produce a firm tenodesis of the tendons of the extensors of the wrist, which, it seems, should be attached after passing them through drill-holes in the radius and ulna.

#### RESUME

Description d'une technique appliquée à l'Hôpital Orthopédique d'Aarhus (Danemark) pour la transplantation des tendons dans les parésies radiales: L'extenseur commun des doigts est activé par la transplantation du fléchisseur cubital antérieur. L'extension et l'abduction du pouce est activée au moyen du grand palmaire ou, dans un cas, du petit palmaire. Dans les cas où les extenseurs du poignet ne sont pas parétiques, ceux-ci peuvent être utilisés pour activer l'extension et l'abduction du pouce.

Les observations portent sur 8 malades: chez deux d'entre

eux, il y avait parésie de l'extenseur commun des doigts et des extenseurs du pouce, tandis que les extenseurs du poignet fonctionnaient normalement. L'auteur les désigne comme des « paralysies profondes ». Chez les autres 6 malades, il y avait parésie de tous les muscles de l'avant-bras innervés par le nerf radial. Elles sont indiquées comme des « paralysies radiales proprement dites ».

Le résultat constaté lors des examens complémentaires ressort du schéma No. 1. Chez le malade No. 8, on ne trouva aucune fonction du fléchisseur cubital antérieur transplanté. Les mouvements actifs du poignet et des articulations métacarpo-phalangiennes des doigts sont supposés être dus uniquement, chez ce malade, aux fléchisseurs des doigts. Chez tous les autres patients, on constata une bonne fonction du fléchisseur antérieur transplanté.

Chez les malades Nos. 4 et 9, on constata l'absence d'extension active de l'articulation métacarpo-phalangienne des doigts. Chez les autres malades la mobilité de cette articulation était normale ou presque normale. Chez tous les malades, la mobilité des articulations inter-phalangiennes était normale et ils pouvaient tous fermer la main normalement ou presque normalement.

Par rapport à la mobilité du poignet et aux forces de la main, ces observations peuvent être divisées en deux groupes: *Groupe A*, comprenant les malades Nos 4, 8, 9, 5 et 10 chez lesquels on constata aux mensurations du dynamomètre que les forces étaient bonnes, mais qu'il y avait restriction de la flexion palmaire du poignet, probablement parce que la suture entre le fléchisseur cubital antérieur et l'extenseur commun des doigts était placée si loin distalement sur les tendons de l'extenseur commun des doigts qu'elle touchait le ligament cubital dorsal. *Groupe B*, comprenant les malades Nos. 1, 2 et 6, chez lesquels le pouvoir de flexion palmaire était fort et la pression minimale à l'examen du dynamomètre, au cours duquel le poignet est forcé en flexion palmaire.

La mobilité du pouce était presque normale et en tout cas absolument satisfaisante au point de vue fonctionnel.

Dans l'ensemble les résultats de l'opération ont été bons et les malades s'en trouvaient généralement très satisfaits. Il est possible que l'on puisse améliorer encore les résultats en pratiquant une tenodèse solide des tendons des extenseurs du poignet qu'il convient probablement d'attacher sur les os de l'avant-bras en les faisant passer par des trous perforés dans ces os.

### ZUSAMMENFASSUNG

Es wird eine Beschreibung der am Orthopädischen Krankenhaus zu Aarhus angewandten Technik der Sehnentransplantation bei Radialisparese gegeben: Der Extensor digitorum communis wird durch eine Transplantation des Flexor carpi ulnaris aktiviert. Die Extension und Abduktion des Daumens wird mit Hilfe des Flexor carpi radialis oder in einem vereinzeltten Falle des Palmaris longus aktiviert. In den Fällen, bei denen die Extensoren des Handgelenks nicht paretisch sind, können diese zur Aktivierung der Extension und Abduktion des Daumens verwendet werden.

Das Material umfasst 8 Patienten; zwei von ihnen zeigten eine Parese des Extensor digitorum communis und des langen Abductors und der Extensoren des Daumens bei Bewahrung der Funktion der Extensoren des Handgelenks. Sie werden als „Profunduslähmungen“ bezeichnet. Bei den übrigen 6 Patienten bestand eine Parese sämtlicher, vom Radialis innervierten Muskeln des Unterarms. Sie werden als „eigentliche Radialislähmungen“ bezeichnet.

Das Ergebnis der Nachuntersuchungen geht aus Schema 1 hervor. Bei Pat. Nr. 8 wurde keine Funktion des transplantierten Flexor carpi ulnaris gefunden. Es wird angenommen, dass die aktiven Bewegungen im Handgelenk und in den Basalgliedern der Finger bei diesem Patienten ausschliesslich eine Funktion der Flexoren der Finger sind. Bei allen anderen Patt. fand man eine gute Funktion des transplantierten Flexor carpi ulnaris.

Die Patt. Nr. 4 und 9 zeigten einen bedeutenden und funk-

tionshemmenden Mangel in der aktiven Extension der Basalgelenke der Finger. Bei den übrigen Patt. war die Beweglichkeit der Basalgelenke normal oder fast normal. Sämtliche Patt. zeigten eine normale Beweglichkeit des Mittel- und Nagelgliedes und eine normale oder fast normale Faustbildung.

Hinsichtlich der Beweglichkeit des Handgelenks und der Kraft der Hand lässt sich das Material in zwei Gruppen einteilen: *Gruppe A*, bestehend aus den Patt. Nr. 4, 8, 9, 5 und 10, zeigte gute Kraft bei Dynamometermessung und eine Einschränkung der Volarflexion des Handgelenks, wahrscheinlich weil die Suturstelle zwischen dem Flexor carpi ulnaris und dem Extensor digitorum communis so weit distal an den Sehnen des Extensor digitorum communis angebracht war, dass sie an das Ligamentum carpi dorsale anstiess. *Gruppe B*, bestehend aus den Patt. Nr. 1, 2 und 6, zeigte eine gute Fähigkeit zur Volarflexion und minimalen Druck bei der Dynamometeruntersuchung; hierbei wurde das Handgelenk zwangsmässig stark volarflektiert.

Die Beweglichkeit des Daumens wurde fast normal und unter allen Umständen funktionell völlig befriedigend befunden.

Die Operationsresultate waren im grossen und ganzen gut, und die Patt. waren im allgemeinen recht zufrieden. Möglicherweise lassen sich die Ergebnisse noch dadurch weiter verbessern, dass man versucht, an den Sehnen der Handgelenksexpensoren eine solide Tenodesse vorzunehmen, die vermutlich an den Unterarmknochen befestigt werden müssen, wobei man sie durch Bohrlöcher führt, die in diesen Knochen anzulegen wären.

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## DISCUSSION

*Langenskiöld, F.*, Helsingfors: As a result of the war in Finland there have been a great number of cases of paralysis of the radial nerve, which could not be cured by suturing the nerve. In these cases *Perthes'* operation, which was the subject of the last lecture, was the treatment of choice, and many of the results obtained have recently been reported by *Saikk* in a supplement to the *Aeta Chirurgica Scandinavica*. In contrast to the lecture, however, we have found that to obtain a good grip it is necessary to secure dorsiflexion of the wrist either by fixing the extensor tendons of the wrist to the radius and ulna, as suggested by *Perthes*, or by transplanting the pronator teres to these tendons by *Jones'* method. There is an exception to this rule: that is, in a paralysis affecting the left hand of a violinist.

## LAMBRINUDI'S OPERATION FOR DROP-FOOT

BY

P. K. K. BENTZON and J. AGERHOLM-CHRISTENSEN

*Lambrinudi's* ingenious operation for drop-foot has not gained the popularity it deserves.

In 1927 *Lambrinudi* described a rather complicated "new operation on drop-foot". He later developed a simplified method which he published in 1932.

In 1937 *Fitzgerald & Seddon* reported a serie of 24 cases. Allthoug their results were promising we have not found other publications on the subject apart from *Hart's* introduction of the method to the American orthopaedic surgeons in 1940. As to our knowledge the operation has not been used in the Scandinavian countries so far we should like to introduce it now.

"The underlying idea", *Lambrinudi* writes, "is a combination of two time-honoured general principles of orthopaedic surgery. I. the best method to stabilize a joint without ankylosing it is to allow it to lock in a normal manner. II. removal of a wedge at the right side is often the best way to correct a bony deformity".

The principle of *Lambrinudi's* "method of correcting an equinus deformity at the sub-astragalar joint" is, when the foot is in complete equinus the posterior tubercle of the talus abuts against the tibia and the foot cannot drop further. Therefore with the talus kept in this position and the subtaloid part of the foot lifted up into a desired position the discomfort of a drop-foot is eliminated and still some important movements in the ankle-joint are preserved.

The surgical procedure is shown in fig. 1: an atypical triple-arthrodesis is performed by removing a wedge of the talus and the shaped anterior "beak" of the talus is locked into a horizontal notch in the naviculare bone.

Fig. 2 shows radiograph of the foot immediately after operation.

It is most advisable to take a preoperative radiograph of

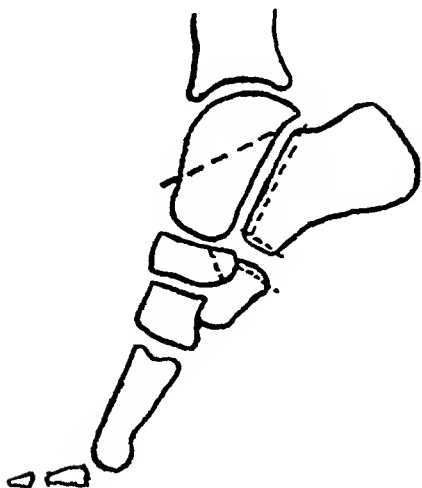


Fig. 1a.

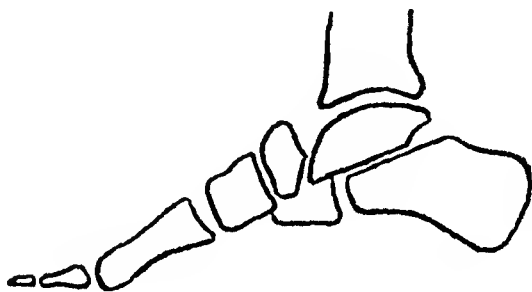


Fig. 1b.

Figs. 1 a and b

illustrate the idea of Lambrinudi's operation on drop-foot.

Fig. 1 a:

the foot is fully plantar flexed. The posterior tubercle of the talus abuts against the tibia. The stippled lines indicate how much of the bones should be removed to obtain the desired position of the foot, which is shown in fig. 1 b.

the foot in complete equinus in order to estimate the size and shape of the talar wedge to be removed.

Lambrinudi devised his operation for a drop-foot with an active calf muscle. But as *Fitzgerald & Seddon* have pointed out it is also of value in the treatment of a flail foot, of the equinus-foot of hemiplegia where the muscles are in imbalance and of "old" club-feet where incongruence of the articular surfaces of the ankle-joint makes it difficult or impossible to tilt the talus back into its normal position. The



operation might be unwise with some shortness of the extremity and if the patient still has to wear long supporting irones due to other muscle paralysis.

Since 1945 the operation has been performed on 23 feet at Orthopaedic Hospital, Århus.



*Fig. 2*

shows the condition immediately after operation. The calculated wedge of the talus has been removed, and the beak-shaped anterior part has been locked into a slot in the navicular bone. The joint surfaces between the os calcis and the astragalus and between the os calcis and the cuboid bone have been removed.

The 23 feet were: 14 of poliomyelitic paralysis (12 with drop-foot and an active calf muscle, 2 with a flail foot), 2 of lesions of the peroneal nerve, 1 of spastic hemiplegia, 4 of "old" club feet, 2 of equinus deformities (1 of muscular dystrofi and 1 of acrocalcinosis of the skin and subcutis).

The youngest patient was 12 years old, the oldest 39 years.

The post-operative course was un-eventfull apart from one case, a 39-years old female polio-case who had a mental disturbance treated in a lunatic asylum. She developed a "post-traumatic dystrofi".

In all other cases radiographs showed sound fusion within 3-4 months.

We believe it is fair to say that when the operation had been done with the correct technic the intended results were obtained: the foot did not drop and some movement was



*Fig. 3*

shows superimposed radiographs of the foot before and after operation to illustrate how the foot is "lifted" at the sub-taloid joints.

retained at the ankle-joint. Fig. 3 shows x-rays before and after the operation.

3 patients had still too much equinus. The method can not be blamed. The surgeon had obviously not removed an adequate wedge of the talus. This should be avoided by a study of the radiograph.

It is too early to give any final results. But our experience agree with those of *Fitzgerald & Seddon*, that this method is superior to other operations as pan-taloid arthrodesis, tenodesis and boneblock operations when used on sound indications and with the correct technic.

It remains to be seen how the ankle-joint will resist a continued strain. An osteoarthritis may develop and may be some cases with a better defined posterior tubercle of the talus will show a more lasting good result.

#### SUMMARY

*Lambrinudi's* operation for drop-foot is described. Since 1945 the method has been used on 23 feet: 14 with sequelae of poliomyelitis, 2 with lesions of the peroneal nerve, 1 with a spastic hemiparesis, 4 with "old" club-feet, and 2 with equinus deformities. The preliminary results are promising.

#### RESUME

Il est question de l'opération de *Lambrinudi* pour le „drop-foot“. Depuis 1945, cette opération a été pratiquée sur 23 pieds: 14 souffrant des suites de polimyélie, 2 avec lésion du nerf péronier, 1 avec hémiparésie spastique, 3 avec pied-bot de longue date et 2 avec déformité de la pointe du pied. Les résultats provisoirement obtenus sont prometteurs.

#### ZUSAMMENFASSUNG

Es wird über die *Lambrinudi'sche* Operation bei „drop-foot“ berichtet. Die Operation wurde seit 1945 an 23 Füßen ausgeführt; 14 mit Folgen einer Poliomyelitis, 2 mit einer Läsion des N. peroneus, 1 mit Hemiparesis spastica, 4 mit alten Klumpfüßen und 2 mit Spitzfussdeformitäten. Die vorläufigen Ergebnisse sind günstig.

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#### DISCUSSION

*Stören, Bentzon.*

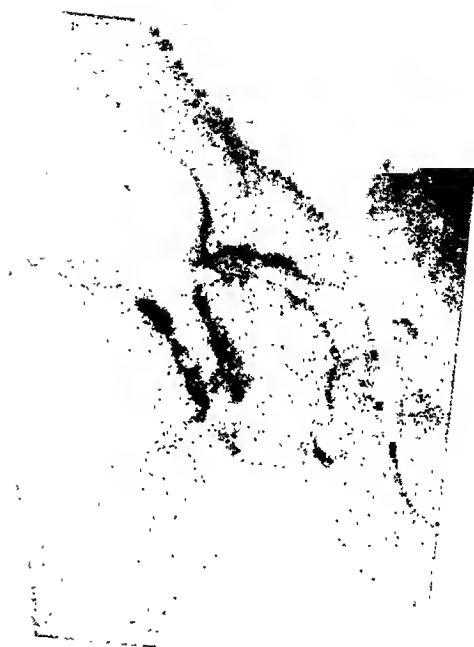
# ON OSTEOSYNTHESIS IN THE TREATMENT OF PSEUD- ARTHROSIS OF THE FEMORAL NECK

BY

SOPHUS VON ROSEN,  
Malmö.

Pseudarthrosis of the neck of the femur has become much less common, since nailing became the usual method of treatment of fractures of the femoral neck. In its place, necrosis of the head has received increasing attention as the most common of the undesirable sequelae of these fractures. Pseudarthrosis is, however, still a problem which demands attention and definite treatment. Sub- or intertrochanteric osteotomy is the most widely used treatment, but even though its results are often satisfactory, one may occasionally see cases in which it is tempting to aim at a better anatomical and functional result. The treatment is usually an osteosynthesis with either some kind of nail or screw or with an inlay bone graft. *Watson-Jones* discusses this treatment in his "Fractures and Joint Injuries". He appears to reserve nailing, with or without simultaneous bone-grafting, for those cases in which there is delayed consolidation without significant displacement and with minimal shortening of the neck.

*Böhler* does not quite agree. He says that he operated one of his 28 cases 22 years after the fracture. He recommended reduction of the fracture by pin traction, and later on nailing. He does not use bone-grafting, which he regards as useless. His enthusiasm for the results is expressed in the following words: "die Pseudarthrose des Schenkelhalses ist also nicht wie man bisher allgemein glaubte durch Bösartigkeit sondern durch besondere Gutartigkeit ausgezeichnet". These words

*Fig. 1.*

Case 1. Woman, aged 60 years,  $1\frac{1}{2}$  years after injury.

*Fig. 2.*

Case 1. After operation (nailing).

seem to be received with reservation even though the two cases I describe might be regarded as confirming them; actually one of the cases had considerable resorption of the neck and complete displacement, which Böhler considers to be a contra-indication to nailing.

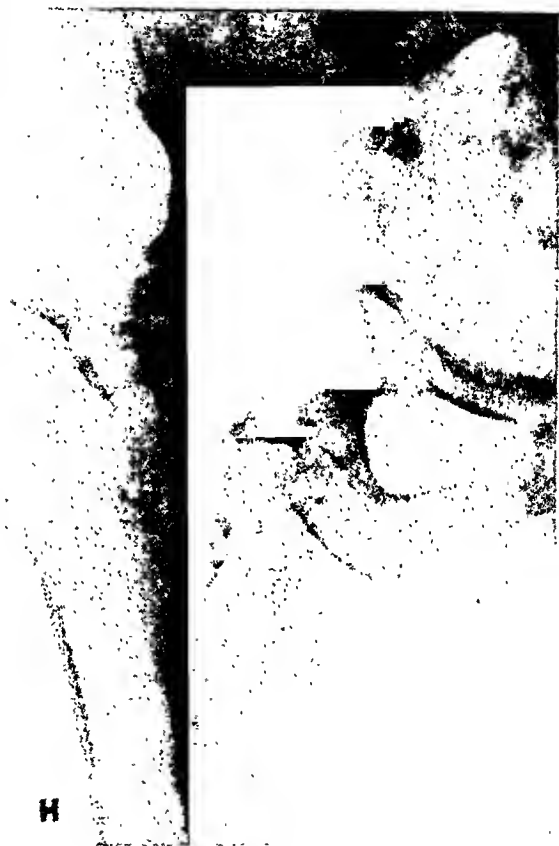


Fig. 3.

Case 1. 7 months after nailing; nail replaced by bone graft.

*Case 1* was a woman, aged 60 years, who had a high fracture of the femoral neck in March 1940. The fracture was reduced and immobilised with plaster elsewhere. The radiograph taken after the reduction showed a good position, but unfortunately only an antero-posterior view had been taken. She was discharged from hospital  $3\frac{1}{2}$  months after the fracture, walking with a stick. I saw her  $1\frac{1}{2}$  years after the accident, when she was complaining of increasing difficulty in walking. Radiography showed pseudarthrosis with external rotation of the lower fragment. (See Fig. 1). I decided to attempt reduction and nailing. At operation, inversion of the thigh to reduce the fracture caused a spiral fracture of the shaft. The operation was continued. When the trochanteric

region was exposed, movement could be felt at the pseudarthrosis. (The fracture of the diaphysis was explained by the softness of the femur; the cortex could easily be pierced with a blunt instrument). A nail was hammered through the pseudarthrosis in good position (see Fig. 2). In view of the fracture of the shaft, traction was applied by means of a pin through



*Fig. 4.*

Case 1. 5 years after operation.

the lower end of the femur.  $2\frac{1}{2}$  months after operation the fracture of the shaft was united, and the pseudarthrosis appeared to be uniting. 5 months after operation the nail, which was loosened was replaced, as a precaution, by a graft from the tibia. 7 months after operation the patient was discharged from hospital. On examination a year later she could walk both up and down stairs. There was practically full range of active movement at the knee; at the hip, there was



*Fig. 5.*

Case 2. Woman, aged 63 years, 11 months after injury.



*Fig. 6.*

Case 2. After reduction by traction.





*Fig. 7.*

Case 2. 6 months after operation (nailing and bone grafting).



*Fig. 8.*

Case 2. 2 years after operation.

60° flexion, 20° abduction, 30° adduction; 1 cm. shortening. No limp on walking (see Fig. 3). 5 years later the patient had further improved. She could go for long walks and had no pain. (See Fig. 4).

*Case 2* was a woman aged 63 years. She had a high fracture of the R. femoral neck in February 1946. The fracture was reduced and immobilised in plaster elsewhere. 2 months later, the plaster was removed, and she was discharged from hospital 4 months after admission, walking with two sticks. She could not raise the lower limb with extended knee while lying on her back. I saw her in January 1947, 11 months after the accident. There was external rotation and shortening. She still walked with two sticks. Radiography showed pseudarthrosis with resorption of the neck. (See Fig. 5). Operation was recommended and was accepted 1 month later. A 4 kg. plaster traction was applied, and 2 weeks later there was a surprisingly good reduction, though there was considerable separation between the ends, due to the resorption. (See Fig. 6). At operation osteosynthesis with a pin and two bone-grafts was done, the grafts being inserted into tracks prepared by drilling. After operation the patient was left free in bed. 2½ months after operation radiography showed beginning callus formation. There was approximation of the fracture ends so that both the nail and the grafts lay partly outside the corticalis. (See Fig. 7). 6 months after operation there was good callus formation. She began to walk with the help of a chair, and was discharged a month later, walking with two sticks. The nail became loose, and was removed in May 1948. At her latest examination, nearly 2 years after operation there was good union (see Fig. 8), but definite signs of necrosis of the head. The patient preferred to walk with a stick. Flexion at the hip: 110°, abduction, 20°; adduction 30°. No pain.

The last case is of special theoretical interest, because the neck has been reformed by replacement in the gap between the two ends of the pseudarthrosis. Thus one may, in some cases, agree with Böhler about "besondere Gutartigkeit". The latest

radiograph, however, shows, as already mentioned, clear signs of necrosis of the head. It is not yet possible to say how far this may adversely affect the future condition, but some deterioration is by no means impossible.

### SUMMARY

The author describes two cases of pseudarthrosis of the femoral neck, treated in one case by nailing and in the other by nailing and bone-grafting. The former case was operated 1½ years, the latter 1 year after the fracture. The latter case is particularly interesting, both because the fracture could be reduced, and because a new femoral neck was formed by filling up the space between the two ends at the pseudarthrosis.

### RESUME

L'auteur décrit deux cas de pseudarthrose du col fémoral traités l'un par enchevillement, l'autre par enchevillement et greffe osseuse. Le premier cas a été opéré un an et demi après la fracture, le deuxième un an après l'accident. Le dernier cas est particulièrement intéressant, à la fois parce qu'il a été possible d'obtenir la réduction de la fracture et parce qu'un nouveau col fémoral a été reformé en remplissant l'espace séparant les deux bouts, à l'endroit de la pseudarthrose.

### ZUSAMMENFASSUNG

Verfasser beschreibt zwei Fälle von Pseudarthrosis colli femoris, die mit Osteosynthese mit Nagel, bzw. mit Nagel und Knochentransplantat behandelt wurden. Der eine Fall wurde 1½ Jahre, der andere 1 Jahr nach dem Unfall operiert. Der letzte Fall ist von besonderem Interesse, einesteils weil man die Fraktur (die Pseudarthrose) reponieren konnte, anderenteils weil durch Ausfüllung der Diastase zwischen den Pseudarthrosenenden ein neues Collum femoris gebildet wurde.

### DISCUSSION

*Wiberg, Silfverskiöld, Thomasen, Bentzon, Slören.*

## A CONTRIBUTION TO THE TREATMENT OF PSEUD- ARTHROSIS OF THE FEMORAL NECK

BY

H. STÖREN

Pseudarthrosis of the neck of the femur is a relatively frequent complication. In a rather extensive series of investigations instituted by the American Academy of Orthopaedic Surgery, *Campbell* and *Smith* found its frequency to be 10 per cent in a material consisting of early and excellently treated fractures of the femoral neck.

From the point of view of treatment, pseudarthrosis of the femoral neck may be divided into the following 3 groups:

*Group I.* Pseudarthrosis where the vitality of the head is impaired, or where its mobility in the acetabulum is lost, as the result either of prolonged pseudarthrosis or of severe arthrosis.

*Group II.* Pseudarthrosis with marked upwards displacement, often accompanied by extensive resorption of the neck.

*Group III.* Pseudarthrosis in which both upward displacement and resorption are less marked. It is for this latter group, which is probably the most common, that the method described here is intended.

The operations which have been adopted for this group are:

1. *Osteosynthesis:* Nailing must be objected to, since in most of the cases it has already been employed, and, except in cases where the original nailing was unsatisfactory, it is not likely to yield any better results under the far less favourable conditions in the pseudarthrosis stage. The combination of nailing with bone-grafting, as we have seen done recently by *Von Rosen* with very good results, is a different matter.

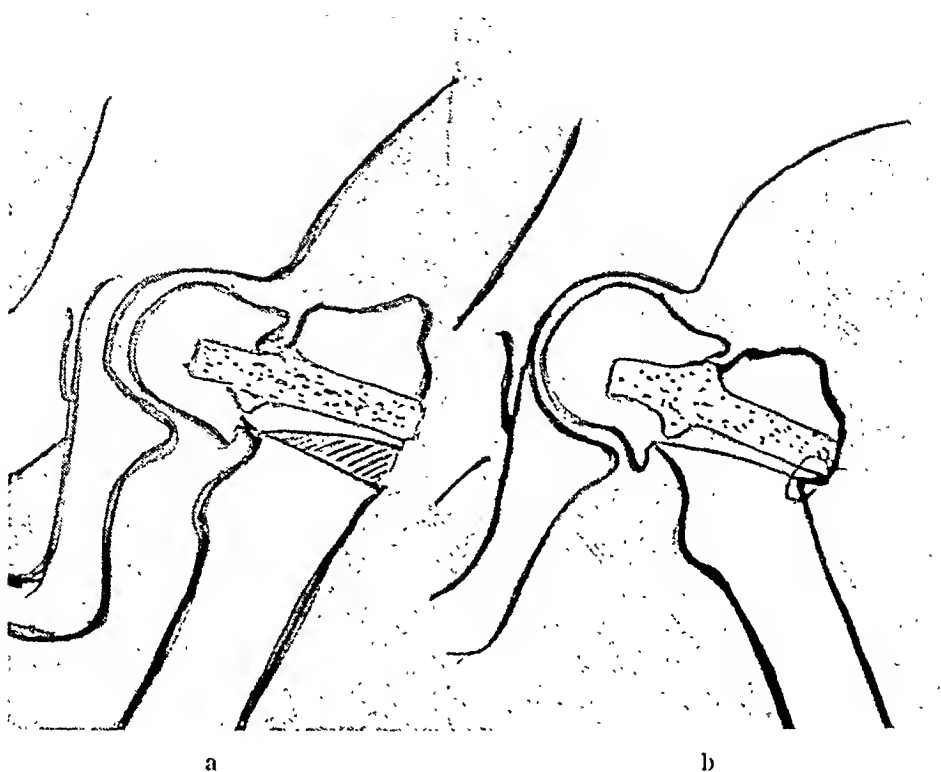
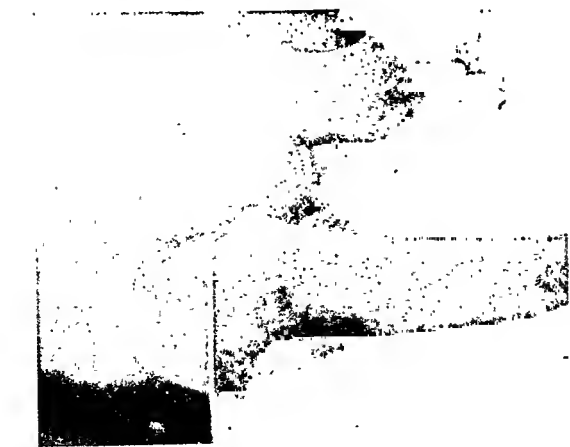


Fig. 1.

- a. The canal and the side parts of the pseudarthrotic space filled up with spongia bone-substance.
- b. Operation concluded. Distal fragment shifted somewhat medially.

2. *Bone-grafting with or without osteotomy.* I have used tibial grafts—(marrow, corticalis, and periosteum) driven through holes drilled in the trochanter, up through the neck into the head combined with subtrochanteric osteotomy—sometimes with and sometimes without good results. Subtrochanteric osteotomy is unsuitable for cases of pseudarthrosis in which there is considerable upwards displacement, since it leads to increased deviation at the pseudarthrosis.

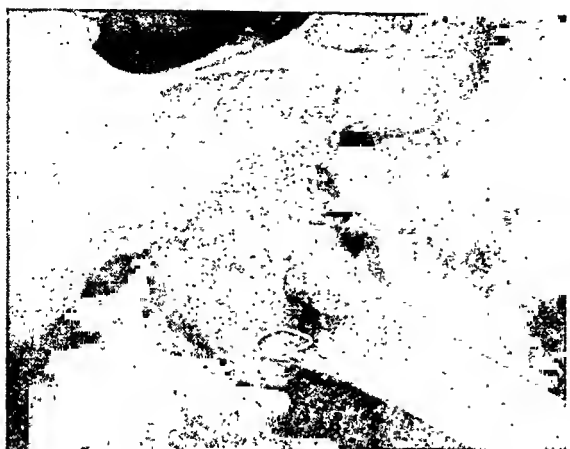
3. *Reich's intertrochanteric osteotomy* with medial displacement of the distal fragment. The object is not only to cause pressure in the line of the axis of the bone, but also to ensure that the distal fragment is in direct contact with the fracture surface of the head.

*Fig. 2 a.*

Radiogram of previously nailed fracture of the femoral neck with pseudarthrosis. Kirschner wire inserted for exploration.

*Fig. 2 b.*

Same pseudarthrosis on operating table at end of operation.

*Fig. 3.*

Same case 3½ months after operation. The patient had been exercising the joint freely for 3 weeks.

The percentage of successful results from this operation was about 80 per cent, but in 25 % of these the union was fibrous. *In 20 per cent of all the cases the result was not good.*

4. *Bracket's operation* has been used for several years at the Mayo Clinic. In this operation the ends of the fracture are exposed and trimmed, the neck is fixed into a cavity prepared in the head, and the greater trochanter is chiselled off and re-attached more distally. A vitallium screw has been used for fixing both the trochanter and the head, in recent years at the Mayo Clinic.

The results obtained from this operation at the Mayo Clinic were good in 90 per cent of the cases.

The procedure must, however, greatly endanger the blood supply of the head—and I cannot find any published investigations on the condition of the head after these operations.

Most anatomical studies have shown that in adults the head is nourished mainly by the vessels running through the visceral part of the capsule, and passing into the edge of the cartilage through numerous vasa nutritia. In about 30 per cent of the cases little or no blood supply passes through the ligamentum teres.

The method which I shall describe here consists in: 1) the removal of as much of the pseudarthrosis tissue as possible, 2) grafting of spongy bone, 3) intertrochanteric osteotomy.

*The method:* A Kirschner wire is inserted to determine the site and direction of the canal to the mode. A track as wide as an index finger is chiselled through the trochanter into the pseudarthrosis, and the connective tissue and fibrous cartilage is excised with a knife and gouge as far out to the sides as possible. The bony tissue is chiselled off and scraped out (with a small sharp spoon bent at an angle) on each side of the pseudarthrosis and as far out to sides as possible. It is surprising how easily the pseudarthrosis can be directly inspected, since there is little haemorrhage if one keeps to the midline. The canal is then prolonged for a suitable distance into the head spongy bone (which is obtained in abundance

from the trochanter) is packed well out to the sides of the pseudarthrosis; a graft which has been taken from the iliac crest and from which the corticalis has been removed is driven into the canal; and finally an osteotomy is made just at the lower corner of the neck (Fig. 1 a). It is usually necessary to remove a wedge of bone to make the angle of the neck sufficiently wide. The distal fragment is shifted medially so as to force the fracture surface of the head as much as possible into a horizontal plane (Fig. 1 b).

When the osteotomy has united after 8 to 10 weeks, the patient is allowed to stand up and put full weight on the limb. Weightbearing in the correct position promotes union.

The pseudarthroses were found to be up to 1 cm. thick, and consisted of tough connective tissue resembling capsule. In one case synovial membrane was also found; it was greatly thickened. In this case there was a considerable upward displacement.

The main points in this method are the extensive removal of the connective tissue of the pseudarthrosis and exposure of the spongy bone on either side, the subsequent filling of the space with spongy bone and the insertion of a graft of spongy bone through the neck into the head, and finally intertrochanteric osteotomy to secure a favourable angle of the neck.

Simple packing with chips of bone cannot give such favourable conditions for union, since there is only a small perforation into the tissue of the pseudarthrosis, corresponding to the size of the piece of bone. On the other hand the pseudarthrosis is a wide gap filled with connective tissue. Intertrochanteric osteotomy alone cannot be expected to bring about union in spite of the improved direction of pressure. This has been shown by follow-up examination: 20 per cent of cases with non-union, and 25 per cent of the remainder with only fibrous union.

Recently I have used this method combined with corrective osteotomy to obtain arthrodesis. After 8 weeks the patient was allowed up in plaster, and after 12 weeks radiography



showed apparent bony ankylosis. Theoretically, however, this was too early for complete consolidation, so I kept the patient in plaster for a further period. When there is severe contracture this method is easier to do than the usual intra-articular arthrodesis.<sup>1</sup>

So far I have only done this operation for pseudarthrosis of the femoral neck in 4 cases and the latest of these is too recent for assessment; to that this paper must be regarded as only a preliminary report. I should, however, be glad if anyone who has a large number of pseudarthrosis cases than I have had would try the method. Certainly technical improvements will be possible. For instance it could be adapted to cases where there is marked upward displacement, reduction being performed after temporary removal of the greater trochanter. This has not as yet been necessary in any of my own cases.

#### S U M M A R Y

The author distinguishes between:

1. Pseudarthroses where the nutrition of the head is impaired, or movement of the head in the acetabulum must be considered lost.
2. Pseudarthroses with marked displacement, often combined with marked resorption of the neck.
3. The most common form of pseudarthrosis, in which the displacement and the resorption of the neck are less marked.

He discusses the most common operations for the two last types. Of these, Reich's osteotomy fails in 20 % of cases; Brachet's operation has satisfactory early results in 90 %, but, as far as the author can find, no late follow-up investigations have been made with a view to the possibility of necrosis

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<sup>1</sup> Since this paper was written, the author has done three more fusion and correcting operations, also one operation of pseudarthrosis, using the same method. The follow-up investigations have shown good results in every case, after a further six months (eighteen months for the first case).

of the head. Further, Brachet's operation must be regarded as dangerous to the nutrition of the head in view of the considerable chance of damaging the already damaged capsular vessels.

The author's method is the following: a canal the width of a finger is chiselled out from the greater trochanter through the centre of the neck into the pseudarthrosis; from here, as much connective tissue as possible is removed through the canal, and the canal is carried on into the head. The line of the pseudarthrosis is packed out to both sides with spongiosa tissue from the iliac crest, and a spongiosa bone graft is driven into the canal and up into the head. Finally an intertrochanteric osteotomy is made, the distal fragment being displaced medially against the pseudarthrosis surface of the head as in a Reich's osteotomy. The author has also used this method for arthrodeses in cases with severe faulty positions. The method is a simpler and less severe operation than an intra-articular arthrodesis which improves the position, and seems, so far, to be no less effective.

#### RESUME

L'auteur distingue entre

- 1) pseudarthroses dans lesquelles la vivification de la tête fémorale est compromise ou sa mobilité dans la capsule articulaire pratiquement supprimée,
- 2) pseudarthroses avec déplacement prononcé, souvent accompagné d'une forte résorption du col fémoral,
- 3) pseudarthroses où la résorption du col et le déplacement sont moins prononcés, ces dernières étant la forme la plus communément observée.

Il mentionne les opérations les plus courantes appliquées à ces deux dernières formes. L'ostéotomie de Reich est déficiente dans 20 % des cas. L'opération de Brachet donne des résultats favorables dans 90 % des cas, mais il n'existe pas, à la connaissance de l'auteur, de comptes-rendus d'examen complémentaires par rapport notamment aux nécroses de la

tête fémorale. Etant donné qu'il est difficile, dans l'opération de Brachet, d'éviter la lésion des vaisseaux de la capsule dont l'état est déjà souvent compromis, il faut considérer que celle-ci est dangereuse en ce qui concerne la vivification de la tête fémorale.

La méthode préconisée par l'auteur consiste à évier un canal de la grosseur d'un doigt du trochanter majeur, par la partie centrale du col fémoral et jusqu'à la fente de la pseudarthrose. Le canal traverse dans la plus grande étendue possible les tissus conjonctifs. Il pénètre un peu dans la tête fémorale. Les deux extrémités de la fente de la pseudarthrose sont recouverts de tissu conjonctif spongieux. Une greffe osseuse d'os iliaque est ensuite enchevillée dans le canal et la tête fémorale. On pratique alors une ostéotomie intertrochantérale en déplaçant le fragment distal médialement vers la surface de la pseudarthrose de la tête, comme dans l'ostéotomie de Reich. L'auteur a également appliqué cette méthode dans les arthrodèses où la position vicieuse est fortement accentuée. Avec un peu de pratique, cette méthode est plus simple et moins radicale que les arthrodèses intra-articulaires de redressement et ne semble pas jusqu'ici avoir été moins efficace.

### ZUSAMMENFASSUNG

Verfasser unterscheidet zwischen:

1. Pseudarthrosen, bei denen die Ernährung des Caput in Mitleidenschaft gezogen ist oder die Beweglichkeit des Caput im Acetabulum als aufgehoben angesehen werden muss.

2. Pseudarthrosen mit schwerer Aufwärtsverschiebung, oft von einer schweren Resorption des Collum begleitet.

3. Die gewöhnlichste Form von Pseudarthrosen, wo die Collumresorption und die Aufwärtsverschiebung weniger ausgesprochen sind.

Er bespricht die gewöhnlichsten Operationen bei den beiden letzten Formen.

Unter diesen versagt die Reich'sche Osteotomie in 20 % der Fälle.

Die Bracket'sche Operation gibt in 90 % der Fälle ein unmittelbar günstiges Ergebnis, es liegen aber, soweit Verfasser bekannt, für diese Operation keine späteren Nachuntersuchungen im Hinblick auf eine Caputnekrose vor. Und die Bracket'sche Operation muss wegen der grossen Gefahr einer Läsion der Kapselgefässe, die schon im voraus oft in Mitleidenschaft gezogen sind, als für die Ernährung des Caput gefährlich angesehen werden.

Die Methode des Verfassers besteht in der Ausmeisselung eines fingerdicken Kanals vom Trochanter major durch die Mittelpartie des Collum zur Pseudarthrosenspalte hinein. Deren Bindegewebe wird durch den Kanal in grösstmöglichem Umfange herausgeschnitten. Man arbeitet sich weiter ein Stück in das Caput hinein.

Die Pseudarthrosenspalte wird zu beiden Seiten mit spongiösem Knochengewebe angefüllt. Dann wird eine Cristaspange in den Kanal und in das Caput hineingestopft. Hierauf wird eine intertrochantäre Osteotomie vorgenommen, bei der das distale Fragment medialwärts gegen die Pseudarthrosenfläche des Caput verschoben wird wie bei der Reich'schen Osteotomie. Diese Methode hat Verfasser auch bei Arthrodesen angewandt, wo starke Fehlstellungen vorlagen. Die Methode ist bei entsprechender Uebung einfacher und weniger eingreifend als eine stellungsverbessernde intraartikuläre Arthrodesis und erscheint bisher nicht weniger effektiv.

#### DISCUSSION

*Wiberg, Silfverskiöld, Thomasen, Bentzon, Stören.*

## ON DENIS BROWNE'S TREATMENT OF CLUB-FOOT

BY

JOH. AGERHOLM-CHRISTENSEN

Since *Denis Browne* in the '30's advocated his treatment of congenital clubfoot his method has been most popular in Great Britain, though it does not seem to be used much on the European continent.

*Verbrugge* introduced the method into Belgium in November '46 and in June '47. *Marique & Steenbruggen* reported that they found the method superior to any other, although no Belgian results have been published.

*Leveuf & Bertrand* have this year written that the method is very little known in France but is very interesting.

The method was introduced into U.S.A. by *Thompson* in 1942. He modified the splint and avoided manipulations. He claims excellent results in all but one of 60 cases. American orthopaedists have mainly used modified forms of the treatment. In 1943 *Jergeson* had treated 52 cases with good results. In 1944 *Bell & Grice* published 46 cases, 11 excellent, 29 good, and 6 fair, and in 1946 *Blumenfeld, Kaplan & Hicks* gave a detailed report of 41 cases. Of these  $\frac{1}{2}$  had excellent results,  $\frac{1}{4}$  had a slight adduction deformity but were otherwise good, while the rest had other minor incomplete corrections.

Unfortunately *Denis Browne* has not published his follow-up results but he claims to be able to correct any simple club-foot and to restore at the same time the muscle function, if treatment is begun early enough. He has abandoned tenotomies.

Since December '46 I have personally treated and followed all new cases of early congenital club-foot, following *Denis Browne's* method and using copies of his splints.

It is well known that the different components of a club-foot are intimately related. The supination, the adduction and the cavus components are due to sub-taloid changes, mainly subluxation in the talo-calcaneo-naviculare joint displacing



*Photo 1.*

the sub-taloid part of the foot medial to the talus, while the equinus component occurs at the ankle joint. As *Brockman* has clearly emphasised correction of one component affects all the others and all must be corrected before the club-foot is cured.

*Denis Browne* prefers to correct the deformities as early as possible without anaesthesia, preferably at one session, and concentrating mainly on the adduction deformity. The foot is then fixed to the splint (see photo 1) with adhesive plaster, and with a piece of felt under the outer side of the forefoot. The other foot is fixed to another splint, without any felt if it is normal. The two splints are joined together by a cross bar, the deformed foot being strongly rotated outwards, a normal foot slightly. When the feet are fixed in this way the child corrects actively the foot's position by kicking and the muscles are exercised. Later, usually when the child is about 6 months old, the flexible and corrected foot is fitted with a

night splint (see photo 2) to maintain the correction. The splint may be used for many months.

This plan has been followed and all patients are now treated as out-patients.

Treatment was begun in 35 cases, but discontinued in 5 cases for reasons not concerning the D.B. method.

30 cases, 21 boys and 9 girls, are still under treatment:



*Photo 2.*

45 feet, 8 right, 7 left, 15 bilateral. Most patients were brought for treatment within the first 2-3 weeks, a few between the 7th and 10th weeks. All degrees of severity were represented.

After 18 months experience we have studied the preliminary results. All feet have been examined by the author both clinically and radiographically. A good clinical result is claimed when the foot is flexible, easily brought into pronation, abduction and 30-60 degrees dorsiflexion and there is active overcorrection. Radiographically the foot is considered good when the radiograph is normal in the dorsoplantar projection.

The preliminary results were as follows:

*Clinically good results: 40 feet, normal radiographs in 33, unsatisfactory radiographs in 7*

(in 5 of these 7 the radiographs showed slight adduction of the fore foot, in the remaining two the angle between the axes of the talus and calcaneus was not quite wide enough).

*Clinically unsatisfactory results in 5 feet, normal radiographs in 2, unsatisfactory radiographs in 3.*

(Of the 2 patients with normal radiographs one had had a severe icterus neonatorum with a haemorrhagic tendency and radiographic signs of subperiosteal haemorrhage of both femurs and tibiae. The right foot was well corrected but active dorsiflexion was not yet satisfactory, although still improving. The other had a dorsiflexion of only 65 degrees.

The 3 with unsatisfactory clinical and radiographic results were: one, a debilitated child, has a passively easily overcorrected foot, but holds the fore-foot in slight adduction; one, whose mother discontinued the treatment for 4 months at a time when the foot was fully corrected, has a dorsiflexion of 80 degrees and radiographically slight adduction and slightly reduced angle between the axes of talus and calcaneus; and one with a troublesome foot complicated by syndactylies of the toes, obviously not a simple club-foot: it is still not quite flexible, dorsiflexion is only 70 degrees, radiographs show some adduction and too narrow an angle between the talus and calcaneus.)

The latest radiographs of each case were shown.

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Again I wish to underline that these are of course only preliminary results, but they have impressed all of us who have followed the cases. We believe that *Denis Browne's* treatment seems to be superior to other methods which have been used in this hospital. The final results can naturally not be seen for the first 4-5 years, but one thing may be stressed: so far it has not been necessary to do a single elongation of the Achilles tendon though in earlier treatment this was a very frequent procedure.

#### SUMMARY

After a brief review of the published results of Denis Browne's method of treating clubfoot, the preliminary results of 18 months' experience with this method are presented. 30



children have been treated: 21 boys and 9 girls, comprising 45 feet: 8 right, 7 left and 15 bilateral. In most cases the treatment was begun within the first 2 to 3 weeks of life, a few between the 7th and 10th weeks. All degrees of severity were included. The feet have been followed both clinically and radiographically. 40 feet are good clinically, of these the radiographs are normal in 33 and nearly normal in 7. 5 feet are not wholly satisfactory clinically, and of these the radiographs are normal in 2 and not satisfactory in 3. The treatment seems to be better than other methods used in this hospital. It is especially notable that it has not been necessary to lengthen the Achilles tendon in any case. The final results will be interesting.

#### RESUME

Après un court aperçu des résultats de Denis Browne publiés jusqu'ici sur le traitement du pied bot, exposé des résultats primaires provisoires observés après 18 mois d'expérience. Le traitement a été pratiqué d'après la méthode de Denis Browne chez 30 enfants: 21 garçons et 9 fillettes, sur 45 pieds en tout. Dans 8 cas, il s'agissait du pied droit, dans 7 du pied gauche et dans 15 le pied bot était bilatéral. Pour la plupart des enfants le traitement a été instauré dans les 2-3ème semaines, chez quelques-uns dans les 7-10ème semaines après la naissance. Ces cas comportaient tous les degrés de gravité. Les pieds ont été suivis ensuite cliniquement et radiologiquement: 40 pieds étaient bons au point de vue clinique, avec des travaux radiographiques normales dans 33 cas et pas tout à fait normales dans 7. Pas absolument satisfaisants au point de vue clinique: 5 pieds dont 2 avec radiographies normales et 3 pas entièrement satisfaisantes. Ce traitement semble meilleur que les autres méthodes employées par cet hôpital. Il est frappant de constater entre autres qu'il n'a pas été nécessaire d'allonger le tendon d'Achille dans un seul cas. Il sera intéressant de voir quels seront les résultats finaux obtenus.

## ZUSAMMENFASSUNG

Nach einer kurzen Uebersicht über die bisher veröffentlichten Ergebnisse der Denis Browne'schen Klumpfussbehandlung werden die vorläufigen primären Ergebnisse nach 18-monatiger Erfahrung besprochen. Die Behandlung wurde ad modum Denis Browne an 30 Kindern durchgeführt: 21 Knaben und 9 Mädchen, insgesamt an 45 Füßen, bei 8 rechtsseitigen, 7 linksseitigen und 15 doppelseitigen Fällen. Bei den meisten Kindern wurde die Behandlung in den ersten 2-3 Wochen begonnen, bei einigen wenigen im Alter von 7-10 Wochen. Alle Schweregrade kamen vor. Die Füße wurden klinisch und röntgenologisch nachkontrolliert: Klinisch gut waren 40 Füße mit normalem Röntgenbefund in 33 Fällen und nicht ganz normalem in 7. Klinisch nicht ganz befriedigend waren: 5 Füße, davon 2 mit normalen und 3 mit nicht ganz befriedigenden Röntgenbildern. Die Behandlung scheint besser zu sein als andere in diesem Krankenhaus angewandte Methoden. Besonders auffällig ist, dass es nicht in einem einzigen Falle nötig war, eine Achillessehnenverlängerung vorzunehmen. Man muss mit Interesse die Endergebnisse abwarten.

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## DISCUSSION

*Nilsonne, Kiær, Thomasen, Silfverskiöld.*

*H. Stören* (Slavern): So far as I have understood from the paper which has just been read, Denis Browne demanded for a good result of the treatment of clubfoot that the atrophy of the leg should not exceed 1 cm. This is to demand something which lies beyond the control of the treatment.

I have for 8 or 10 years been treating club-foot by redressement and plaster bandaging, as soon as possible after birth. Often I have had cases only 1 or 2 days old, and in many of these the muscles of the leg were already markedly atrophic: this was particularly noticeable in cases of unilateral club-foot. Probably in these children the embryonic muscular anlage itself has been imperfect, and no treatment will be likely to cure this.

Denis Browne also stipulated that there should be complete correction at the first session. This is not always feasible even with children 1 or 2 days old. As early as this I have often met with very severe contracture, and complete correction at the first attempt was not possible. Resistance to treatment and a tendency to relapse in these cases cannot be unreservedly attributed to the method by which they have been treated. They were unfavourable cases in the embryonic stage, owing, in my opinion, to defective innervation; this is, of course practically impossible to prove directly.

Further, it is rather too much to say that Denis Browne's treatment of clubfoot is the ideal method. I do not think that this can be said of any method of treatment for a disorder which presents as many variations as does clubfoot. Here, as in so many other conditions, one must treat the cases individually, according to their nature and to the course which they take. Personally, as I have said before, I have for many years used redressement and plaster as soon as I could get the child for treatment. And when Thomasen in 1912 submitted his method of redressement I adopted it with some minor modifications. I have, however, used plaster and not

plain bandages to keep the foot in position. The results of clubfoot treatment ought not to be submitted until after 8 or 10 years. Not until then can we get some idea of the final result, and in many cases not even then.

*Poul Guildal* (Copenhagen): Denis Browne's method no doubt has certain advantages over some methods of treating congenital clubfoot. That good results are obtained when the patients are brought for treatment in their first weeks does not say so very much, since one can nearly always get quite good results whatever treatment one uses. It is difficult to judge from so short an observation period what the results will be in cases which are brought for treatment later. With nearly all methods of treatment the primary results are good, but relapses do not appear until later, and there is no doubt that in certain cases these relapses can be very resistant and require treatment of both the soft and bony parts for many years.

It is difficult to understand how the muscles can be better preserved with Denis Browne's method than with the usual plaster treatment, since the legs are if anything more firmly fixed than when they are free from each other. It is also difficult to believe that correction of the different components of a club-foot should be better with this method which uses a stiff firm plate than with a plaster bandage which can be adapted to the individual components. But one cannot judge whether the method represents a real advance before one sees the late results. There is no doubt that it is technically just as difficult as the usual manipulations and plasterings.

*Agerholm-Christensen*: I am afraid Dr. *Stören* has misunderstood me. *Denis Browne* claims only to be able to correct any *simple* club-foot. He too knows the most resistant cases as we see them in arthrogryphosis. He prefers to correct the foot in one session—if possible. I did not call it the ideal method, but I believe it is the best method which has been used in this hospital. I disagree with Dr. *Guildal*: it is much

easier to apply the *Denis Browne* splint than a plaster of Paris bandage to a baby foot. I think that the fixation of both feet together gives the child much more kicking exercise than plaster. Dr. *Thomassen* refers to his paper "Der angeborene Klumpfuss" (*Acta Orthop. Scand.* XII. 33. 1941). I can only say that the importance of correcting the inversion of the calcaneus has been stressed for many years (e.g. *Bankart, Elmslie, MacMurray, Platt* in 1920), and that the dorso-plantar radiographic projection has long been used (before *Wisbrun*). The first radiograph I showed to day was a reproduction from *Brockmann's* book published in 1930. *Thomassen* recommended in 1941 manipulations and fixation with flannel bandages. He had treated 7 cases which had been followed up to an average age of 13 months; in 3 an elongation of the Achilles tendon was done. I have been through the notes of 60 club feet treated by this technic in the Orthopaedic Hospital, Cph. since 1943/44. By 1947/48 44 had had an elongation of the Achilles tendon usually in the first year, 45 showed adductus and 17 varus positions. I believe the future will show that with *Denis Browne's* treatment elongation will rarely be necessary, and that the varus position will be corrected; but we may have trouble with the adductus position. The treatment does correct this position, but I am afraid that some children will not have sufficient muscle power to maintain the correction.

# FRACTURES OF THE CARPAL BONES, WITH PARTICULAR REFERENCES TO THE SCAPHOID

BY

KJELD ANDERSEN & FREDERIK THERKELSEN

## AUTHORS' ABSTRACT:

The material submitted comprises 119 cases of intra-articular fractures of the scaphoid and 27 fractures of the other carpal bones.

One hundred *fractures of the scaphoid* were followed up with a view to the functional result, and 98 with a view to the radiological result. The average follow-up period was 8.4 years.

This study revealed the decisive importance of immobilizing the fracture immediately after the accident. Union occurred in 23 of 25 cases immobilized within a week of the accident.

The sooner immobilization takes place, the shorter the union time (minimum 16.3 weeks—maximum 94 weeks).

When there was delayed union, drilling by Beck's method had a favourable effect in 4 out of 8 cases, whereas 2 cases of obvious pseudarthrosis were unaffected.

It was found that if pseudarthrosis was already present when the fracture was diagnosed—in 29 cases of this material—union did not result, even from prolonged immobilization.

In the writers' opinion the main cause of delayed union and pseudarthrosis formation is inadequate immobilization: the position of the scaphoid in both rows of bones and the great excursion of the fragments in movements at the wrist makes a very accurate and prompt immobilization necessary if union is to be obtained. Moreover, fractures in the proximal third of the bone seem to unite less readily than those in the distal two-thirds.

In the cases with union the functional result was perfect in 29, good in 12, and poor in 4. As to the pseudarthroses the result was perfect in 6, good in 22, and poor in 14.

As regards the 18 operated cases the results correspond to those obtained in the pseudarthroses.

A total of 27 cases of *fractures of other carpal bones*, comprising separation of chips off the scaphoid, semilunar, pisiform, and cuneiform, union was present in all the cases radiographed—and the functional results were perfect, except in 2 cases. Some of the cases had immobilization for a few weeks—others had no treatment.

#### DISCUSSION

*Novotny, Bentzon, von Rosen.*

## CONSERVATIVE TREATMENT OF CLAVICULAR FRACTURES

BY

HANS NOVOTNY,  
Oslo.

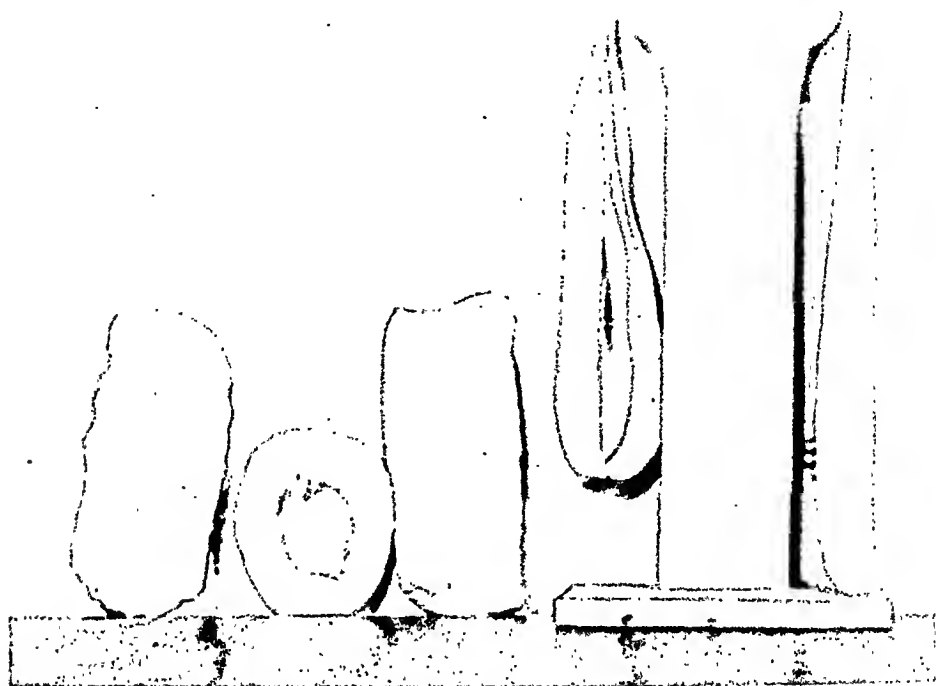
According to Kreisinger, more than 200 methods of treating clavicular fractures have been described. This fact alone proves that the problem of how to obtain perfect results in treating clavicular fractures is not a simple one to solve.

I personally have never seen any bad results from operative reduction and fixation of the fracture if the foreign material used for the fixation is removed after consolidation of the fracture, but certain complications have been described in the literature and undoubtedly opening a fracture situated so close to the large vessels and nerve trunks is not without risk of complications. Moreover, the presence of unresorbable matter so near to the surface of the skin may cause irritation.

It is, therefore, not surprising that one often finds warnings against routine operation on clavicular fractures from the most experienced traumatologists, as, for example, Watson Jones. There will, however, always be certain clavicular fractures in which operation is necessary to avoid a decrease in the patient's working capacity. In order to reduce the number of operations to as few as possible it is necessary to find a very secure conservative method of fixing the fracture. The main problem in the treatment of clavicular fractures, excepting transverse fractures which may also be difficult to reduce, is how to fix the broken ends.



It is said that clavicular fractures almost always unite, and that, even though the ends are in a bad position, at least a fibrous, if not a bony union takes place. This is, however, not completely accurate, as one does see cases without either fibrous or bony union and where the patient is unable to do heavy work or sport, until the condition is changed. Further



*Fig. 1.*

Two pieces of cardboard, one padded, the other unpadded.  
One cottonwool-ring. The bar and the belt.

in the clavicular fractures which eventually unite, the process may be so slow, if the fracture is not properly fixed, that a patient who earns his living by heavy work may have serious economic difficulties.

To avoid such complications, I have since 1935 used a plaster method which I will describe here.

In my experience, two things have prevented more extensive use of plaster of Paris bandages in clavicular fractures. First, the difficulty of holding the fractured ends in position during the application of the plaster, and second, the discom-

*Fig. 2.*

The ring and the belt are applied to the patient.

*Fig. 3.*

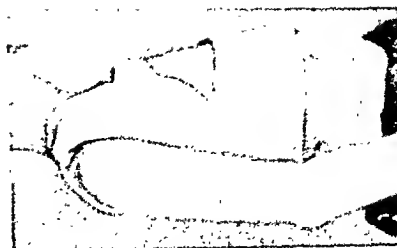
The bar has been placed between assistant and patient.

*Fig. 4*

showing how the bar has been placed over the plaster slabs crossing the back.

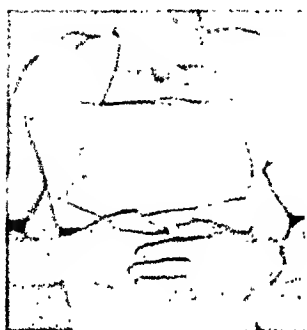
*Fig. 5.*

Front view of the finished bandage.

*Fig. 6.*

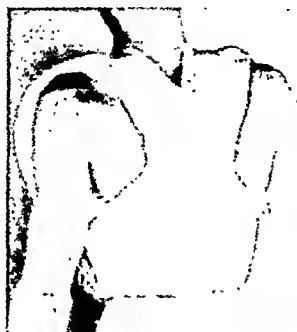
Side view.

fort caused to the patient by the figure-of-8 bandaging usually recommended, which compresses and constricts the axillæ. I have tried to overcome these disadvantages by the technique described below.



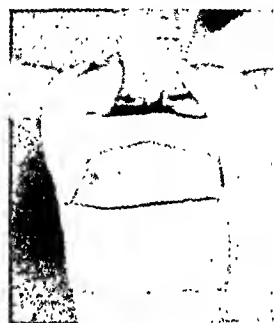
*Fig. 7.*

Showing hands meeting in front.



*Fig. 8.*

Back view.



*Fig. 9.*

Range of elevation of arms.

Small children can usually be treated successfully by figure-of-8 bandages of flannel. But here also one must be very careful to avoid constricting the axillæ. Older children are treated in the same way as adults—either, in less serious cases by a kind of bridle bandage, which is excellent, or by a plaster of Paris bandage.

A plaster bandage improves the cosmetic result in two ways. Firstly, it maintains the complete or partial reduction and prevents gradual loss of the position while the ends are uniting. Secondly, the callus formation is less bulky with good fixation.

For the application of my bandage, one needs a fairly tightly bound ring of cotton wool, a belt, two oblong pieces of cardboard padded with cotton wool, a bar with a supporting plate at one end and a pressure knob at the other, and three long and one short plaster of Paris slabs. Two assistants are needed.

The pieces of cardboard are prepared by tearing off the edges so that they lose all sharpness. The cardboard should

not be too thick and must be pliable. The prepared pieces are padded and placed over the anterior circumference of the shoulders so that they reach from the trapezius muscle to a little below the axillary fold. The large vessels and nerves in the axilla are thus protected against pressure from the plaster. At first I used only thick saddle felt under the plaster slabs instead of cardboard, but it failed to protect the axillae.

Before reducing the fracture the ring of cotton wool is attached to the skin between the shoulder blades with a solution of mastix. The fracture is then reduced in the ordinary way under local anesthesia, using 10 cc of a 1 per cent Novocainadrenaline solution. The assistant then takes charge of the patient, and sits behind him, while the bar is placed between them, with the supporting plate against the assistant's chest and the pressure knob against the padded ring between the patient's shoulders.

Now, while the assistant pulls back the patient's shoulders or upper arms, using the bar as counter pressure, the surgeon places the cardboard on the shoulders, and passes the belt behind the neck, forward over the shoulders and back under the axillae to the assistant who now takes the two ends of the belt and pulls backwards with them instead of with the shoulders themselves. Then, while the fracture is held in correct position, the operator carries out any minor local corrections at the site of the fracture. The belt forces the patient to bend his head while the plaster is applied, and this position probably helps to reduce the fracture and keep it reduced since it relaxes the sternocleidomastoid muscle, which tends to displace the medial fragment slightly upwards.

When the patient's position is satisfactory, the first plaster slab is placed round the thorax below the nipples. The other two plaster slabs should be a little longer. They are applied from the posterior lateral region of the circular plaster slab across and up the back to the front of the opposite shoulder, so that they cover the belt and the cardboard, and then under the axilla, back to be attached to the first slab. When the plaster slabs are passed across the back, the knob of the bar

must be lifted away for an instant by another assistant, who first grasps the patient's head and then the bar and presses them gently apart, while the first assistant slightly relaxes the pressure of his chest on the supporting plate. It is best to begin with the affected side. A depression in the plaster is thus produced under the knob of the bar, it does not, however, cause any discomfort to the patient because of the padded ring, but exerts a light pressure between the shoulder blades and tends to correct the fracture. To avoid secondary displacement of the fracture a short plaster slab is placed across the chest to prevent approximation of the plaster loops. Finally, the slabs are fixed by a few turns of plaster bandage. It is best to twist the slabs as they pass under the axillae, so that they are stronger and narrower here. The belt is now removed, and plaster is cut so that the patient's hands can meet in front, and the plaster does not irritate. If necessary, minor corrections for the final adjustment of the plaster should be made in the next few days.

#### SUMMARY

Due to the fact that clavicular fractures with considerable displacement sometimes take a long time to consolidate, and that in certain cases even a pseudarthrosis may develop, because of insufficient immobilisation of the fracture by soft or semi-rigid adhesive tape or bridle bandages, the author has since 1935 used his own plaster of Paris bandage, which is mainly shaped like a shoulder bridle.

The reasons for the difficulties of using plaster of Paris in clavicular fractures are discussed and their avoidance with the new technique is described.

In order to immobilise the fracture while the plaster is being applied a bar with a supporting plate and pressure knob and a belt are used. The bar is pressed between the patient's shoulder-blades, and the same assistant who presses on the bar pulls the shoulders back with the belt. Padded cardboard is applied to protect the nerves and vessels of the axillae.

## RESUME

En partant du fait qu'il faut souvent un temps assez prolongé pour arriver à la réduction définitive d'une fracture de la clavicule avec forte dislocation, soignée seulement par emplâtres mous ou demi-solides, ou avec des bandages en forme de brides, et que dans certains cas il se forme même de la pseudarthrose, l'auteur s'est, depuis 1935, servi d'un bandage de plâtre de son modèle.

Les causes des difficultés qui surgissent en employant le plâtre pour ces fractures ont été discutées, et il est décrit comment on peut éviter ces difficultés en ayant recours à la nouvelle méthode.

Le bandage conserve, en principe, la forme d'un bandage-bride, et on l'applique à l'aide d'un instrument très simple, un bâton en bois avec une pelote de pression et une plaque de soutien. On se sert, en outre, d'une ceinture. Ces deux objets sont employés pour la coaptation de la rupture pendant le plâtrage, un aide rentrant les épaules avec la ceinture en pressant le bâton entre les omoplates. Pour protéger les vaisseaux et les nerfs de la région axillaire, on applique des plaques en carton, flexibles et ouatées, placées d'une manière bien déterminée.

## ZUSAMMENFASSUNG

Ausgehend von der Tatsache, dass es in Fällen von schwereren Schlüsselbeinbrüchen manchmal lange dauert bevor sie fest werden und dass es manchmal sogar zu Pseudarthrosen kommt, wenn man nur mit weichen oder halbsteifen Pflaster oder Turnisterverbänden zu fixieren sucht, hat der Verfasser seit 1935 eine eigene Methode der Gipsverbandbehandlung angewendet. Die Bandage hat im Prinzip die Form eines Turnisters.

Die Gründe fuer die Schwierigkeiten in der Verwendung von Gipsbandagen beim Schluesselbein-bruch sind erörtert und ihre Vermeidung mit der neuen Methode ist beschrieben.

Um die Bruchenden während des Gipsens zu fixieren.

verwendet man einen Stab mit einer Druckpelotte und einer Stützplatte, ferner einen Gürtel. Der Stab wird vom Assistenten zwischen die Schulterblätter des Patienten gedrückt, während der Gürtel vom selben Assistenten benützt wird um die Schultern des Patienten zurückzuziehen. Zur Beschützung der Nerven und Gefäße in den Axillae verwendet man dünne, wattierte Pappendeckelscheiben.

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#### DISCUSSION

*Wallgren.*

## THE SCALENUS ANTICUS SYNDROME

### *Report of an Instructive Case.*

BY

RAGNAR MAGNUSSON, M.D.,  
Stockholm.

The aetiology of the symptoms of brachial neuralgia which usually occur in the scalenus anticus syndrome has been variously interpreted by different writers. While some consider that the compression of the subclavian artery is the essential cause of the symptoms, others have stressed the significance of the neurological changes. Finally there is a third group who believe that the variety of the symptoms proves that vascular and neurological disturbances are present together. *Karlén's* observations are of interest in this connection. At operation no oscillometric changes could be produced by compressing the artery, but they could be produced by compressing the brachial plexus. This observation supports the view of *Telford* and *Stopford* that the vascular symptoms are caused by irritation of the sympathetic fibres in the brachial plexus.

It is not yet certain whether a possible cervical rib plays a primary or secondary rôle in the onset of the symptoms. *Adson* and *Coffey's* investigations showed that only a small percentage of their patients with cervical ribs had any symptoms (36 out of 303 cases). On the other hand *Annersten* points out in a recent paper that even enlargement of the costo-transverse process is a valuable sign in the diagnosis of scalenus anticus syndrome, where there are also neurological or vascular symptoms in the arm.

The procedure to be used when a cervical rib is present



has been much discussed. *Adson* and *Coffey* say that the rib should be resected if it compresses the artery or is longer than 5 cms. *Collins*, *Patterson* and others emphasise the importance of removing a cervical rib when there is longstanding, persistent disturbance. *Wanke* also considers that resection is practically a *sine qua non* for a satisfactory result. On the other hand, cases are described in the literature in which removal of the cervical rib also had no positive effect until



*Fig. 1.*  
Before operation.

the scalenus anticus was divided at a second operation. (*Bertelsmann*, *Theis*).

The foregoing is intended as background to an account of a case who was operated on this year at the Orthopaedic Clinic of the Karolinska Sjukhus in Stockholm. It is reported in order to throw light both on the importance of a cervical rib in causing symptoms and also on the period between scalenotomy and recovery.

The patient was a woman aged 36 years (Journ. No. 1398/48), who for 12 years had suffered from pain down the ulnar side of the right upper limb. At first the pain had been intermittent but for the last 4 years it had been continuous. The limb was weak and the patient could neither lift nor carry even light objects, partly because of the weakness and

partly because these actions increased the pain. The pain was also increased by turning her head to the right. Examination showed marked atrophy of the thenar muscles, but none of any other muscles (see Fig. 1). The reflexes were equal on the two sides; no sensory disturbance could be detected; oseillometry was the same on the two sides. The skin temperatures on the right arm and forearm were  $2^{\circ}$  lower than on the left side, and on the right dorsum and palm of the hand



*Fig. 2.*

they were  $3^{\circ}$  degrees lower. A sweat test showed hyperhidrosis in the ulnar area of the R. hand. Electromyography of the thenars, hypothenars and interossei suggested peripheral motor neuron damage. Bilateral cervical ribs were shown on the radiographs (see Fig. 2).

At operation a hard rather firm contracted scalenus anticus muscle was found. The muscle compressed the artery against the apex of the cervical rib. Immediately after division of the muscle the patient reported spontaneously a feeling of relief with almost complete disappearance of the pain, a feeling of warmth in the whole limb. The post-operative course was uncomplicated.

On the day after operation the skin temperatures were the same on both sides. 6 weeks after operation electromyography showed considerable improvement, with an increase in the number of potentials. Oscillometry and a sweating test at

this time showed no difference between the two sides. The sweating test was repeated again later, and still no difference could be detected between the two sides. The atrophy of the thenar muscles was already less marked 2 weeks after the operation and at a recent examination it could only just be detected.

In spite of considerable compression of the artery, there were no vascular disturbances, though there were marked neurological signs and symptoms. The rapid recovery was the most remarkable finding. Previously it has not been known how rapidly the repair process can act. In this case the limb was normal soon after the scalenotomy. The sweat tests and skin temperature measurements indicated a disturbance of the sympathetic nerve fibres. It is impossible to assess exactly how far the symptoms can be referred to this sympathetic disturbance, but in view of the experiences of other authors—partly reported in the present paper—it is probable that a considerable part of the symptoms were of sympathetic origin. Slight irritation of a peripheral nerve may cause hyperhidrosis and division of the nerve to a cutaneous area will cause anhidrosis. The topographical distribution of the changes in the hand in this case can probably be explained by greater compression on the cranial part of the plexus. This would cause considerable muscle atrophy and hypohidrosis in the radial and median areas and hyperhidrosis in the distribution of the ulnar nerve.

This case agrees in these characteristics with two cases reported by *Telford* in a series of 92 scalenotomies. Hyperhidrosis was present in both cases and was interpreted by *Telford* as the result of irritation of the sympathetic fibres. It is very probable that symptoms arising in the sympathetic fibres not infrequently play a considerable part in the scalenus anticus syndrome.

In addition this case demonstrates that it is not necessary to remove even a relatively large cervical rib to obtain permanent disappearance of the symptoms.

## SUMMARY

A case of scalenus anticus syndrome in a woman aged 36 years, who had had symptoms for 12 years is reported. Thorough investigation (including electromyography, sweating tests, etc.) showed neurological changes without any circulatory disturbance. At operation there was found to be considerable compression of the subclavian artery; a large cervical rib was not removed. There was marked improvement after division of the muscle and rapid regression of the signs. For reasons which are further discussed in the paper, the author considers it probable that the compression of the artery was not an important factor for the appearance of the symptoms which were caused by the compression of the nerves resulting in symptoms from the sympathetic nerve fibres.

## RESUME

Un cas de syndrome du scalenus anticus chez une femme âgée de 36 ans, chez laquelle des symptômes avaient été observés 12 ans auparavant, est rapporté. Un examen approfondi (électromyographie, épreuve de la transpiration, etc.) a montré des modifications neurologiques sans aucun trouble circulatoire. A l'opération, on trouva une très forte compression de l'artère sous-clavière; une grosse côte cervicale n'a pas été enlevée. On constata une amélioration marquée après la division du muscle et une régression rapide des signes de la maladie. Pour des raisons que sont discutées d'ailleurs dans l'article, l'auteur considère comme probable que la compression de l'artère n'était pas un facteur important par rapport à la manifestation des symptômes qui étaient causés par la compression des nerfs, provoquant des symptômes du côté des fibres du nerf sympathique.

## ZUSAMMENFASSUNG

Es wird über einen Fall von Scalenus anterior-Syndrom bei einer 36jährigen Frau berichtet, die seit 12 Jahren Sym-

ptome hatte. Eine gründliche Untersuchung (einschliesslich Elektromyelographie, Schwitzproben usw.) ergab neurologische Veränderungen ohne irgendwelche Zirkulationsstörungen. Bei der Operation wurde eine beträchtliche Kompression der Arteria subclavia gefunden; eine grosse Halsrippe wurde nicht entfernt. Nach einer Teilung des Muskels wurde eine merkliche Besserung und ein rascher Rückgang der Symptome erzielt. Aus Gründen, die in der vorliegenden Abhandlung näher erörtert werden, hält Verfasser es für wahrscheinlich, dass die Kompression der Arterie für das Auftreten der Symptome nicht von entscheidender Bedeutung war, die vielmehr durch eine Kompression der Nerven verursacht waren, die zu Symptomen von seiten der sympathischen Fasern führte.

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#### DISCUSSION

*Wiberg.*

## ON THE TECHNIQUE AND POSSIBILITIES OF RECONSTRUCTIVE HAND SURGERY

BY

ERIK MOBERG

The aim of reconstructive hand surgery is naturally to restore the function to injured hands. The basis of the reconstruction has been set out by Sterling Bunnell: that a hand with some form of sensation and prehension is better than any prothesis, while, on the other hand, one which cannot be made to grasp with feeling is not worth retaining, even if it looks like a hand. The same may be applied to a certain extent to the different parts of the hand.

Difficulties arise on three essential points, when it is a question of performing such reconstructions with positive results.

1. *The diagnosis.* It is important to ascertain in detail before beginning treatment which tendons are not functioning, and why, whether movement is restricted by skin, ligament, joint, or tendon, etc. These problems of diagnosis will not be discussed here, but it should be pointed out that they are the biggest part of the problem for the hand surgeon, and it should be emphasised that the most frequent cause of poor results is incorrect or incomplete diagnosis, even by those with long experience.

2. *The operative technique.* This must be "atraumatic", which necessitates operating with delicate instruments in a completely bloodless field. Remains of scar tissue often impair the final result. The gliding surfaces cannot be treated with too great care, and every damage to their surface causes adhesions. Infection must be avoided, and this applies not



*Fig. 1.*

Tendon suture in progress. Note the need for a completely bloodless field, if a gliding function is to be obtained. Swabs must not be used. The only hold of the tendon which is allowed is by forceps on its tip, which is later cut off.

only to infection leading to suppuration, but also to the slighter degrees, which cause only temporary redness and swelling. Suppuration generally makes further reconstruction impossible for ever, while milder infection prevents the desired gliding movement. Even post-operative swelling of the tissues must be prevented by elastic compression bandages. (Demonstration of operative technique with coloured illustrations).

3. *The planning of a reconstruction.* This depends entirely upon what can and what cannot be done. Neither sensation nor nutrition can be transplanted, but both can be improved by excising scar tissue from round the nerves and vessels; this can often make an atrophic, cold, clammy, hand, warm and soft again. But it is not possible to replace sensation and nutrition which have been completely lost. This implies, at

least in our cold climate, that thumbs or fingers built up by transplantation have a very limited working value, if any.

However, the possibilities of reconstruction are considerable. Plastic skin methods are frequently used, and are particularly practicable in the hand. The correct incisions must be chosen, and planned so that secondary scar contractures, which are unfortunately still common, are avoided.

Suture of sensory nerves has been successfully performed as long as 5 or more years after complete division of a nerve. Suture of a digital nerve, provided it is surrounded by soft tissue, has a particularly favourable prognosis.

Bone operations, e.g. substitution of metacarpal bones, lengthening of thumb stumps and straightening crooked parts, are widely used. For joints, arthrodesis for instability (ligament injuries) is often important. In the metacarpo-phalangeal joints so-called capsulectomy, with resection of the collateral ligaments can restore mobility to joints which have stiffened in extension due to the all too common shortening of the ligaments here, and joint plastics also have possibilities (except in the thumb). Neither of these operations has yet appeared to be of value for the interphalangeal joints, where stability is essential for function.

As regards tendons and muscles the recent advances have been of great importance. The technique of free tendon transplantation has been so developed that its results are quite as reliable as those of other operations.

Similarly, transference of muscle power has now a much wider use than formerly, and a suitable functioning system can be built up by distributing the available muscle on the remaining mobile parts, e.g. the different operations for restoring opposition and adduction to the thumb, and substitution of extensors and flexors and the restoration of lost interosseous function (demonstration of results).

The results of skin reconstructions, arthroplasties and free tendon grafts are shown.

In multiple reconstructions the question is, when and in what order should the different defects be treated. Treatment



includes, of course, not only surgery but also splinting, etc. Nerves always have priority. A multiple reconstruction often begins first with the repair of the skin, which is followed by repair of the nerves. No joint can be made to function without sensation, and it is equally useless to attempt to reconstruct the muscular system with muscle and tendon until the joint to which its effect is transmitted has free passive mobility. While reconstruction of one system is in progress, the others must not be neglected, or it may happen that by the time the skin and nerve reconstructions are completed the condition of the joints and muscles makes a favourable final result impossible. This is particularly liable to happen when the treatment has been divided into e.g. plastic surgery for treatment of the skin, neuro-surgery for repair of the nerves, and, finally, orthopaedic surgery for treatment of the joints and muscular apparatus. The hand must be treated as a unit, and favourable results can only be obtained by those prepared to learn to work on all its tissues. (Demonstration of extensive reconstruction cases).

#### S U M M A R Y

Recent advances in the surgery of the hand have entirely changed the possibilities of restoring function to disabled hands.

The particular diagnostic and technical difficulties encountered in this work are stressed. The planning of hand reconstruction by treating skin, nerves, skeletal system and tendons is discussed, and results are demonstrated. Multiple reconstructions of a number of tissues of the hand can only be carried out successfully by a surgeon who can work on all the parts affected, and good results will not be obtained in hand surgery if the treatment is distributed amongst different specialists.

## RESUME

Les progrès de la chirurgie de la main, réalisés au cours de ces dernières années, ont entraîné des vues toutes nouvelles sur les possibilités de rendre aux mains invalidisées leurs fonctions normales.

On souligne les difficultés particulières que l'on rencontre dans le domaine diagnostique et technique. Le programme du travail de reconstruction, en tenant compte des possibilités existantes par rapport à la peau, aux nerfs, au système osseux et aux tendons, est examiné et il est donné un exposé des résultats pouvant être obtenus. Les reconstructions multiples, portant sur la plus grande partie des tissus et des organes de la main, ne peuvent être exécutées avec chance de succès que par ceux travaillant avec tous les éléments de la main. C'est pourquoi, la chirurgie de la main ne peut pas être divisée en différentes spécialités si l'on veut obtenir des résultats favorables.

## ZUSAMMENFASSUNG

Die Fortschritte der Handchirurgie in den letzten Jahren haben zu einer ganz neuen Beurteilung der Möglichkeiten geführt, invalid gewordenen Händen ihre Funktionstüchtigkeit wiederzugeben.

Die besonderen Schwierigkeiten, die auf diagnostischen und technischem Gebiete vorliegen, werden hervorgehoben. Die Projektierung der Rekonstruktionsarbeit hinsichtlich der bezüglich Haut, Nerven, Skelettsystem und Sehnen gegebenen Möglichkeiten wird besprochen und das Ergebnis demonstriert. Die multiplen Rekonstruktionen, die mehrere Gewebe und Organe der Hand umfassen, können mit Erfolg nur von jemandem ausgeführt werden, der sich für die Arbeit mit sämtlichen Elementen der Hand qualifiziert hat, und die handchirurgische Praxis lässt sich nicht in verschiedene Spezialitäten aufteilen, wenn das Ergebnis gut werden soll.

## DISCUSSION

*Agerholm-Christensen, Bentzon, Moberg.*

## A SIMPLE INSTRUMENT FOR A MODIFIED BANKART'S OPERATION FOR RECURRENT DISLOCATION OF THE SHOULDER

BY

JOHN AGERHOLM-CHRISTENSEN

The most difficult and time-consuming part of *Bankart's* operation for recurrent dislocation of the shoulder is to drill the holes in the anterior margin of the glenoid and to stitch the capsule.

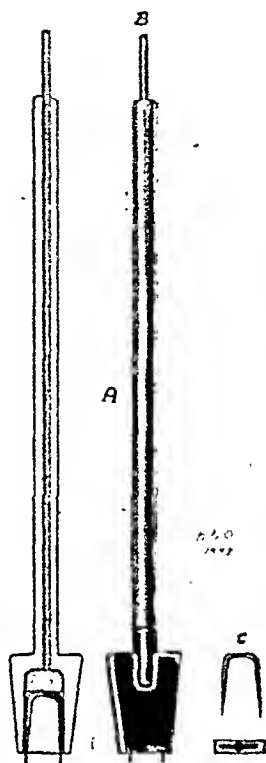
Many orthopaedic surgeons have avoided this difficulty by fixing the capsule with staples or nails, and instruments for this purpose have been invented.

Visitors to our hospital have found the instrument I have used most simple and have encouraged me to publish it.

It is made to my drawings by Mr. Haut in our hospital workshop. The instrument consists of a spade-shaped holder (A) within which is a rod and piston (B). The staple (C), made of stainless steel, is placed in the spade-end of the holder so that its points are just free enough to hold the capsule in situ before hammering. (The legs of the staple can be spread if necessary to fix it firmly in the holder). When the rod is hammered completely into the holder the distal end of the piston is flush with the lower end of the holder and the staple is in position in the bone. The holder is 18 cm. long, the staple is 1 cm. wide.

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I should like to thank Dr. K. K. *Ortmann* for his drawing of the instrument.



## RESUME

Démonstration d'un instrument de construction très simple pour l'enfoncement d'un crampon destiné à fixer la partie antérieure de la capsule de l'épaule au margo glénoïde dans l'opération modifiée de *Bankart* pour luxation habituelle antérieure de l'épaule.

## ZUSAMMENFASSUNG

Demonstration eines einfachen Instruments zum Einhammern einer Krampe zur Fixierung des vorderen Teils der Schultergelenkkapsel an den Margo glenoidalis bei einer modifizierten *Bankart'schen* Operation wegen habitueller vorderer Schulterluxation.

OLECRANON FRACTURES TREATED IN THE  
ORTHOPÆDIC HOSPITAL, COPENHAGEN 1936—47  
A FOLLOW-UP EXAMINATION

BY  
INGEBORG LOU

In 1947 Francis M. McKeever and Ronald M. Buck published in the Journal of the American Medical Association 10 cases of fracture of the olecranon, treated by excision of the proximal fragment and plastic operation on the triceps tendon. The authors maintain that the fragment can be excised when only the coronoid process and the distal vertical part of the olecranon's joint surface is preserved. They maintain that this treatment gives good and early movement, good power of the triceps and little inconvenience from the elbow-joint, and conclude that:

1) pseudarthrosis of the olecranon should be treated by this method.

2) bone-grafting should not be done in these pseudarthroses.

3) severely comminuted fractures of the olecranon should be treated immediately by excision of the fragments and a plastic operation on the triceps tendon.

4) Older patients with fresh olecranon fractures should be treated by this method.

5) Fragments of the olecranon which do not form part of the joint surface should be removed.

6) One need not fear instability of the elbow-joint if the coronoid process and the distal vertical part of the joint

surface of the semilunar (trochlear) notch is preserved. They consider that up to 80 % of the semilunar notch can be removed without fear of instability of the joint.

7) There is no danger of significant triceps insufficiency even when large fragments of the olecranon are removed.

Watson-Jones recommends excision of the fragment in older patients, especially when the fracture is high and the fragment includes less than  $\frac{1}{3}$  of the semilunar notch. He considers that the method has the advantage that the elbow-joint is not immobilised for a long period (10 days), while McKeever and Buck immobilise in a plaster cast for 3 weeks, followed by 10 days in a sling and then active exercise. Since these authors claimed such excellent results in both fresh and old fractures, I decided to follow up the cases of olecranon fracture which had been seen and treated in the Orthopaedic Hospital in Copenhagen 1936-47, to discover whether there were any grounds for believing that the results of treatment would be better if the olecranon fragments were removed in more cases than had been our custom.

During the period mentioned 45 patients with olecranon fractures had been treated; there were 23 men and 22 women; 10 had been treated mainly elsewhere, and 35 had been treated mainly in this hospital. The following methods were used:—

- 1) Sling.
- 2) Plaster, with or without preliminary reduction.
- 3) Osteosynthesis with
  - a) screws
  - b) Alemann's nail
  - c) Wire or Damyl thread.
- 4) Removal of the fragment.

Table I shows that of 45 patients treated 39 were followed up. Of these 39, 2 were treated with a sling, 12 with plaster, 22 by osteosynthesis, and 3 by removal of the fragments. Of the 6 patients who could not be found 3 had had plaster and 3 osteosynthesis.

Table II shows how the fractures occurred; of the 45 cases the origin of the fractures was unknown in 2; in only 4 was it produced by direct trauma at work, in 6 by complicated

TABLE I  
*Olecranon Fractures treated at the Orthopaedic Hospital,  
 Copenhagen 1936-47.*

	Total	Followed up	Not followed up
Sling .....	2	2	
Plaster			
with reduction .....	2	1	1
without reduction .....	13	11	2
Osteosynthesis			
a) screw .....	4	3	1
b) Alemann's nail .....	8	8	
c) Wire or Danyl .....	13	11	2
Removal of fragment .....	3	3	
	45	39	6

TABLE II  
*Origin of Injury.*

Total No. of Injuries	Fall on the arm	Road Accident	Direct Trauma at work	Unknown
45	33	6	4	2

injury (road and sport accidents) while in 33 the patient fell on the arm while walking in the street or in his own home or by falling down stairs, etc. The observation period varied between 4 months and 14 years (this last case was a patient who had been treated elsewhere for an olecranon fracture 12 years previously). 31 patients have been observed for over a year. (Table III).

The age distribution of the patients is shown in Table IV.

TABLE III  
*Period under Observation.*

1 Year or less	1-2 Years	3 Years	4 Years	5 Years and more
8	11	5	2	13

TABLE IV

Method of Treatment	Age groups				Total
	Under 18	18-40	40-60	ov. 60	
Sling .....	2				2
Plaster					
with reduction .....	1				1
without reduction ...	4	1	1	5	11
Osteosynthesis					
a) screw .....			3		3
b) Alemann's nail ...		4	3	1	8
c) Wire or Danyl .....	1	7	2	1	11
Removal of fragment .....			3		3
	8	12	12	7	39

The majority, 24, are within the wage-earning ages, from 18 to 60 years, but, as has already been mentioned, only very few were injured at work. They include most of the patients who were treated by osteosynthesis.

TABLE V  
*Duration of Immobilisation.*

	2 weeks or less	2-4 weeks	5-6 weeks	7-8 weeks	ov. 8 weeks	Un-known	Total
Sling .....	1					1	2
Plaster							
with reduction .....		1					1
without reduction	2	5	3	1			11
Osteosynthesis							
a) screw .....	1		2				3
b) Alemann's nail		4	2		1	1	8
c) Wire or Danyl	2	5	1	2		1	11
Removal of fragment		1				2	3
	6	16	8	3	1	5	39
Under 18 years .....	2	4	1			1	8
18-40 .....	1	4	3	2		2	12
40-60 .....	2	4	3		1	2	12
over 60 .....	1	4	1	1			7
	6	16	8	3	1	5	39



Table V shows how long immobilisation was continued, in relation to both the method of treatment and the patient's age. Only one case was immobilised for over 8 weeks; it was immobilised for 12 weeks and will be discussed later.

TABLE VI  
*Unable to Work.*

	1 Month or less	1-2 months	3-4 months	5-6 months	ov. 6 months	Un- known	Total
Sling .....	1					1	2
Plaster							
with reduction .....	1						1
without reduction	1	6	1			3	11
Osteosynthesis							
a) screw .....			2			1	3
b) Alemann's nail		3	3		2		8
c) Wire or Danyl	1	5	1	1		3	11
Removal of fragment	1	2					3
	5	16	7	1	2	8	39
Under 18 years .....	3	2				3	8
18-40 .. .....	1	6	1	1	1	2	12
40-60 .. .....	1	5	4		1	1	12
over 60 .. .....		3	2			2	7
	5	16	7	1	2	8	39

Table VI shows how long the patients were unable to work in relation to both the method of treatment and to their age. It shows that only 2 patients were off work for more than 6 months; the rest returned to work from 1 to 6 months after injury. 21 of the 39 cases who were followed-up returned to work within 2 months; of the 24 patients in the age-group 18 to 60 years 13 were at work within 2 months.

Table VII shows the result of treatment in relation to the method and the age-group. 38 of the 39 cases are able to do full work, though 6 of these must be considered to have serious trouble (reduced joint movement, reduced power, or pain). 11 have insignificant impairment, usually slight restriction of extension without otherwise any triceps insuffi-

TABLE VII  
Results of Treatment.

	Perfect	Minor troubles	Major troubles not interfering with work	Major troubles reducing working capacity	Total
Sling .....		2			2
Plaster					
with reduction .....	1				1
without reduction .....	8	2	1		11
Osteosynthesis					
a) screw .....		3			3
b) Alemann's nail .....	3	2	2	1	8
c) Wire or Daryl .....	7	1	3		11
Removal of fragment .....	2	1			3
	21	11	6	1	39
Under 18 years .....	5	2	1		8
18-40 „ .....	7	1	4		12
40-60 „ .....	5	5	1	1	12
over 60 „ .....	4	3			7
	21	11	6	1	39

ciency. The remaining cases are perfect and it is interesting to note that these fractures did not have serious after-effects in any of the older patients. Our oldest patient was 95 years. The 11 patients who had unimportant after-effects will not be considered further, since there were similar after-effects in some of the patients in the American material. Nor shall I discuss further the cases with perfect results, since the methods used are shown in the tables. Rather will I go through the 7 cases with serious disabilities, of whom, however, 6 are fully employed in their usual occupations. Some are office-workers and others light labourers.

Only one is unable to work in his usual occupation, that of groom.

67/45. A 46-year old groom, who was kicked on the right olecranon by a horse, and received a fracture which split the whole olecranon, the fracture line running from 1 cm

below the tip of the coronoid process on the joint surface obliquely posteriorly and downwards to 2-3 cm distal to the joint. He was treated in Department I of the Orthopaedic Hospital. 2 weeks after the injury reduction and fusion with Alemann's nail was tried without success. Later, reduction was attempted using a wire through the forearm just above the wrist joint, and 6 weeks after the injury a further osteosynthesis was made using a thicker nail, which held the fracture securely. Plaster for 2 months; the nail was removed at the same time as the plaster. The position appeared to be quite good, though there was considerable decalcification and undoubted incongruence of the joint surfaces.

On examination 2½ years after the injury the right elbow movements were: flexion 130-80°, a few degrees of supination, and pronation 70°. There were pain and crepitation in the joint on movement. The patient was able to work a little now and then, but not steadily. If one wonders whether his condition would have been better if the olecranon fragment had been removed, one must, I think, suppose that it would not have been better, since the fracture line extended too far down the ulna, and the greater part of the semilunar notch was on the loose fragment, leaving only a small part of the joint surface on the coronoid process, so that his elbow-joint would presumably have been unstable and unsuitable for his work.

10074/44. A 9-year-old girl treated elsewhere with plaster for fracture of the left olecranon. She was seen in the Orthopaedic Hospital in October 1944, 2 months after the injury. Radiography showed the results of a comminuted fracture. The semilunar notch was well preserved. Flexion was 150-30°; there was no pain. No further treatment was given beyond active exercises, and the patient was not seen again until the follow-up examination in Nov. 1947. Flexion at the elbow was considerably reduced, to 140-30°. She complained of weakness of the elbow on movement and discomfort in the joint. Radiography showed a deformity of the olecranon with at least one of the original fragments in a position which prevented movement, that is to say, extension. After removal of this fragment

and a plastic triceps operation the range of movement was improved to 30-165°, and was painless.

It is noted that this is the only patient treated with sling or plaster who had serious disability later.

This patient benefitted from the operation recommended by the Americans, since the extension in the elbow-joint was improved by 25°.

3424/47. A 30-year-old housewife and grocer's assistant, treated elsewhere 6 months previously for fracture of the right olecranon by osteosynthesis using an Alemann's nail. She came to the Orthopædic Hospital in April 1947 because of reduced movement in the elbow-joint and pain in the shoulder, arm and forearm. Flexion of the elbow was 160/75°. Radiography showed, as well as an old olecranon fracture (in good position), patchy decalcification of the olecranon: no definite evidence of arthrosis.

With heat treatment the condition improved, and at examination 1 year after injury flexion in the elbow-joint was 165-50°; there was no evidence of triceps insufficiency, but radiography showed deformity of the joint. This patient was able to work after 7 months. One could of course try chiselling off the olecranon spike, but it is not certain that the condition would be improved.

6688/43. A 25-year-old female accountant, treated in Department I of the Orthopædic Hospital for a 2-day-old fracture of the olecranon, running transversely across it, so that the separated fragment was about 3 cm long, and included nearly half of the joint surface. An osteosynthesis using an Alemann's nail was done, and she returned to work 6 weeks after operation. Everything went well, though the joint movement was a little reduced, until 5½ months after operation, when she clung too hard to a tram which was starting, and refractured the bone: it was put in plaster for a month. Result: Pseudarthrosis. When she was examined 4 years after the first fracture, flexion was 160-40°, there was slight crepitation on movement of the joint, full pronation and supination; occasional pain, but not enough to prevent

her working. Radiography shows pseudarthrosis and incongruence of the joint. She is reluctant to have an operation, and can certainly only be helped by removal of the fragment and a plastic operation on the triceps tendon.

*3109/46.* A 36-year-old housewife treated elsewhere by osteosynthesis with wiring. Infection occurred postoperatively. At examination at the Orthopædic Hospital 6 months after operation there was found to be considerable reduction of movement and pain when movement was attempted. With heat treatment and discontinuation of the massage and exercises ordered elsewhere there was fair improvement. On examination 2 years after injury there was reduced movement and pain in the elbow-joint (Flexion 110-65°; supination and pronation 70°). Radiography showed severe arthrosis in the elbow-joint. She is able to do her work.

She has a marked arthrosis as well as infection in her history, so that operation is contra-indicated.

*3265/46.* A 43-year-old waiter with a fresh comminuted fracture of the olecranon, treated in Department II of the Orthopædic Hospital, with osteosynthesis using Danyl sutures after reduction of the fracture. Plaster for 4 weeks. Able to carry on with his work 3 months after injury. At examination flexion was 155-50°, pronation full and supination nearly full. There was occasional tenderness of the elbow region with crepitations on movement; some triceps insufficiency. Radiography showed an irregular semilunar notch and arthrosis, but otherwise good shape of the joint.

It is possible that this patient could have been benefitted by removing the two fragments originally, since only about  $\frac{1}{3}$  of the semilunar notch had been fractured for half the bone's width although for the other half of the width more than half of the notch was lost.

*4064/45.* A 22-year-old small farmer, treated elsewhere 12 years before he was seen at the Orthopædic Hospital, for a fracture on the right olecranon which had been treated by wiring. The patient had been in hospital for 15 days; it is not known how long the elbow was immobilised. 4 months after

operation suppuration occurred and the wire was removed.

Examination 12 years after the injury showed a pseudarthrosis at the site of the fracture, a piece of the olecranon  $1\frac{1}{2}$  cm long being separated from the rest.

When re-examined 2 years later, 14 years after the accident, he was working as a cement worker; sometimes he had a few sharp pains at the site of the olecranon. Flexion  $160-50^\circ$ , supination and pronation were full. Slight triceps insufficiency. 1 cm atrophy of the arm.

This patient could have been benefitted by excision of the fragment and a triceps tendon plastic operation when he was first seen 12 years after the injury, but, since 2 years later he was fully able to do heavy work, one did not like to recommend an operation.

The results of the different methods of treatment given do not differ much from one another. It is not surprising that 6 of the 7 patients with serious after-results are found in the group treated by osteosynthesis, since most of the severest fractures are found in this group, and many of them belong to the wage-earning age-group. 2 of the cases evidently had had osteitis postoperatively. No conclusions can be drawn from the fact that no patient treated by removal of the fragment had serious after-effects, since the fragments removed were small, and there are only 3 such cases.

4 of the 7 patients with serious complaints were between 18 and 40 years, 2 between 40 and 60; none were over 60, though there were 7 patients over 60, the eldest being 95. Only one was under 18. Certainly many of those between 18 and 60 had greater strain on the joint at work, as a result of which arthrosis develops more readily, and, when present, gives more trouble than to a patient who is not working. Only 3 of the patients whose period off work is known were unable to work for over 4 months, and one, already mentioned, must be said to be permanently disabled. As I have already stated in going through the histories I think that 3 of the patients would have been benefitted by excision of the fragment and a triceps plastic operation, 1 primarily, 2 secondarily, apart

from the young girl in whom the operation was done 3 years after the injury, and whose condition was definitely improved. I think one should consider removing the olecranon fragment in those cases in which one cannot obtain good position either by open or closed reduction, and in which the fracture line meets the joint surface on the vertical part of the olecranon; also in cases where there are small fragments lying under the skin, and causing tenderness of the elbow; and, finally, in cases where a disabling pseudarthrosis develops after treatment.

#### SUMMARY

The results of 45 olecranon fractures treated in the Orthopaedic Hospital, Copenhagen, are reported. 39 of these were studied with special attention to the possibility of obtaining better results by excision of the proximal fragment, combined with a plastic operation on the triceps tendon.

The treatments which had been used were:

- 1) sling,
- 2) plaster with or without reduction,
- 3) osteosynthesis using a) a screw,  
b) Aleman's nail,  
c) wire or Danyl,
- 4) removal of the fragment.

The last-mentioned treatment was used in only 3 cases, where quite small fragments were removed, and in one case who was found to have marked impairment of extension at the follow-up examination. There was definite improvement in this case after removal of the fragment.

Out of all the cases followed up one had serious reduction of his working capacity, 6 had a major disability, which did not however interfere with their work, 11 had a minor disability, and 21 had definite good results.

The follow-up showed that 4 patients would have benefited from initial or later excision of the proximal fragment with a triceps plastic operation. This operation seems to be indicated in cases where the proximal fragment includes only

the vertical part of the semilunar notch, and in which a good position can be obtained neither with closed nor open reduction; also in cases in which small subcutaneous fragments cause tenderness in the elbow, or a disabling pseudarthrosis develops after treatment.

### RESUME

Communication du résultat du traitement de 45 fractures de l'olécrâne traitées à l'Hôpital Orthopédique de Copenhague.

39 de ces cas ont été examinés ultérieurement pour voir notamment s'il était possible d'obtenir de meilleurs résultats en extirpant le fragment proximal de l'olécrâne et par opération plastique du triceps.

Le traitement appliqué a été:

- 1) mitella
- 2) plâtre avec ou sans reposition
- 3) ostéosynthèse par
  - a) vis
  - b) clou Alemann
  - c) fil métallique ou damyl
- 4) extirpation du fragment.

Ce dernier traitement n'a été appliqué que dans 3 cas où il s'agissait de tout petits fragments et dans un cas dans lequel un nouvel examen montra qu'il y avait une grosse défectuosité d'extension. Dans ce cas, l'extirpation du fragment a provoqué une amélioration sensible.

Dans les cas examinés à nouveau, on a fait les constatations suivantes: capacité de travail réduite de manière permanente dans un cas, 6 malades se plaignaient d'inconvénients sérieux qui ne les gênaient cependant pas dans leur travail, 11 souffraient de légers inconvénients et 21 étaient réellement bons.

Il ressort des examens pratiqués que pour 4 malades il aurait mieux valu extirper immédiatement ou plus tard le fragment proximal et pratiquer l'opération plastique du triceps. Cette opération semble indiquée dans les cas où le frag-



ment proximal ne comprend que la partie verticale de l'incisura semilunaris et où l'on n'obtient pas une bonne position en pratiquant la reposition ouverte ou fermée, ainsi que dans les cas où de petits fragments sub-cutanés provoquent des sensations douloureuses dans le coude, ou bien encore lorsqu'il se développe des pseudarthroses gênantes après le traitement.

### ZUSAMMENFASSUNG

Es werden die Ergebnisse von 45 Olekranonfrakturen mitgeteilt, die im Orthopädischen Krankenhaus in Kopenhagen behandelt wurden. 39 davon wurden nachuntersucht, besonders im Hinblick darauf, ob durch Exstirpation des proximalen Olekranonfragments und Vornahme einer Tricepsplastik ein besseres Behandlungsergebnis zu erzielen gewesen wäre.

Es wurden folgende Behandlungen angewendet:

- 1) Mitella,
- 2) Gips mit oder ohne Reposition,
- 3) Osteosynthese mit
  - a) Schraube,
  - b) Alemann'schem Nagel,
  - c) Metalldraht oder Damyl.
- 4) Entfernung eines Fragments.

Die letzte Behandlung ist nur in 3 Fällen angewendet worden, wo es sich um ganz kleine Fragmina handelte, und in einem Falle, der bei der Nachuntersuchung einen grossen Extensionsdefekt zeigte. — Die Entfernung des Fragments erwies sich in diesem Falle als eine wesentliche Besserung des Zustandes.

Von allen nachuntersuchten Fällen hat einer dauernd herabgesetzte Arbeitsfähigkeit, 6 haben wesentliche Beschwerden, die jedoch ihre Arbeitsfähigkeit nicht beeinflussen, 11 unwesentliche Beschwerden; 21 sind unbedingt gut.

Ans der Nachuntersuchung geht hervor, dass man 4 Patienten hätte besser helfen können, wenn man sofort oder später das proximale Fragment exzidiert und eine Triceps-

plastik gemacht hätte. Diese Operation scheint in den Fällen angezeigt zu sein, wo das proximale Fragmen nur den vertikalen Teil der Incisura semilunaris umfasst, und wo man durch offene oder unblutige Reposition keine gute Stellung erzielen kann, sowie in Fällen, in denen kleine subkutane Fragmente Schmerzen im Ellbogen verursachen, oder wo sich nach der Behandlung eine Beschwerden verursachende Pseudarthrose entwickelt.

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## THE EFFECT OF TETRAETHYL AMMONIUM BROMIDE ON DYSBASIA ARTERIOSCLEROTICA

BY

JØRGEN STAUN<sup>1</sup>

Since *Acheson* and *Moe* in 1945 demonstrated the specific action of tetraethyl ammonium bromide in blocking the autonomic ganglia, they and other workers (*Lyons et al.* and *Berry et al.*) have published the results of further investigations into the effects of this substance on various disorders of the vascular and autonomic nervous systems.

The best results of its use have been obtained in the treatment of peripheral vascular disorders, since, according to publications by *Berry* and his associates, this substance produces a temporary vasodilatation, which is just as marked as that which follows sympathectomy. Injected intravenously it should be an unfailing diagnostic test and, in addition, it is reported to have a good therapeutic action, even in advanced cases of vascular disorders.

In Sweden, *Larsson* and *Frisk*, and later *Ejrup*, have published results of research in this field.

*Larsson* and *Frisk* used big doses, 6-7 ml., intravenously, and up to 16 ml. intramuscularly, given at one injection, without secondary effects. In four cases they found, contrary to *Berry*, that peripheral procain block of the tibial nerve and spinal anaesthesia both had better results than tetraethyl ammonium bromide.

*Ejrup* has pointed out the importance of giving the injection slowly, at about 1 ml. per minute.

In normal individuals, as far as is known, tetraethyl am-

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<sup>1</sup> In collaboration with Hagbart Starklint.

monium bromide always produces vasodilatation and a quick rise in the skin temperature of the extremities.

*Slaughter, Brown and Wakim* demonstrated plethysmographically that the blood flow in the extremities increased after the administration of 3 ml. doses of tetraethyl ammonium bromide. In normal individuals there was an average increase of 100 % in the upper and 135 % in the lower extremities.

During the last 18 months experiments have been carried out at the Copenhagen Orthopaedic Hospital, Dept. 2, to determine the action of tetraethyl ammonium bromide in patients with peripheral vascular disorders and posttraumatic dystrophy, and—as control—in a few patients with non-vascular disorders. A preliminary report of these experiments was given by Dr. Starklint at the meeting of the Orthopaedisk Selskab in Copenhagen in January, 1948.

The preparation used ("Etylon") is a 10 % solution of tetraethyl ammonium bromide.<sup>1</sup>

The following technique was used in the so-called "Etylon test". The lower extremities of the patient were exposed to room temperature for half an hour, after which up to 5 ml. of Etylon were injected intravenously slowly over two to three minutes, with careful observation of the blood pressure and pulse rate, and temperature-readings from the big toe, the dorsum of the foot and the leg. A vasodilatation test by *Gibbon and Landis'* method and other examinations necessary for establishing a diagnosis had been carried out previously.

Etylon was also given therapeutically by intramuscular injection. First 6-8 ml. and then  $3 \times 10$  ml. injections were given at intervals of a week. Experience showed this dosage to be too small and too infrequent, and in the past 12 months two injections have been given per week. We are now giving the injections every second day in increasing doses, but 10 ml. was the standard dose in the cases reported in this paper.

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<sup>1</sup> The Danish pharmaceutical manufacturers "Pharmacia", who make the solution under the name of "Etylon" have kindly supplied the necessary quantity of the material.

The secondary effects most frequently observed were a metallic taste and dryness in the mouth, slight dizziness, a fall in blood pressure, a rise in pulse rate and transient accommodation pareses. Considerable falls of blood pressure were seen in only two cases. One rose again spontaneously. The other, which fell from 210 to 50 mm. Hg. rose again immediately after a subcutaneous injection of 0.5 ml. adrenaline. The patient only felt slightly dizzy and clinically did not appear to be on the verge of collapse.

According to the literature temporary paresis of the intestine and bladder are other possible secondary effects.

The action on the vessels is felt as transient paraesthesiae in the extremities, followed by numbness and a "cool sensation" in the hands and feet, and, within 5 minutes, a sensation of warmth, which is accompanied by a rise in the skin temperature of the extremities. This paper will show that we, like *Larsson* and *Frisk* found that tetraethyl ammonium bromide has an undoubted effect and is of diagnostic, as well as therapeutic, value. Probably its most important use will be in vascular disorders in which the spastic element is predominant. However, the number of patients whom we have treated has not been large enough to prove this, and the pathological pictures have been so various that we have not wanted to include many of them in this paper. But it has been among this type of patient—in whom vasospasm predominated—that we have observed the most encouraging effects of tetraethyl ammonium bromide.

We shall only deal here with patients with the signs and symptoms of intermittent claudication of arteriosclerotic origin.

A summary of the results obtained is given below.

Arteriosclerotic intermittent claudication .....	12 patients
Improvement in claudication .....	8 ..
Disappearance in coldness of feet .....	4 ..
Objective improvement in the appearance of the feet .....	3 ..

## Reflex vasodilatation and rise in skin

temperature	more than 2° C .....	8	..
	" " 4° C .....	5	..
	" " 8° C .....	3	..

Twelve patients, including two women, all with advanced and confirmed arteriosclerosis have been fairly easy to compare. We have not included any patients who were having any other treatment at the same time as the tetraethyl ammonium bromide injections. The exclusion of these cases from the paper, and of patients with gangrenous lesions from the treatment, accounts for the small number of cases reported.

The ages of the patients varied from 43 to 63. Seven cases were examined well over twelve months, three only four months and two between six and twelve months after treatment.

After treatment with tetraethyl ammonium bromide the claudication has noticeably improved in eight of the 12 cases, and very noticeably in 4 of these 8.

It must be admitted that our best criterion of a favourable effect on the vascular disorder is the subjective improvement in the patient's dysbasia. All the patients treated have given satisfactory information on the distances they have been able to walk before feeling cramps in the calf, or pain or tiredness in their legs. We have come to the conclusion that, in future, a standardised walking test with a definite pace rate, controlled by a metronome and performed under experienced supervision, should be adopted since tests of function, such as the *Lewis* test, with or without resistance and with or without elevation, and the *Moskowitz* test, give results which vary too much with different examiners.

But it is worth noting that in the patients who reported improvement in their dysbasia definite objective signs of an increased blood-flow in the lower extremities were found.

Certainly some importance may be ascribed to the patients' statements that they do not suffer so much from cold feet, since this symptom causes great discomfort, and its disap-

pearance is sure to be noticed. The 8 patients whose dysbasia improved had all suffered from cold feet. One noticed an improvement in this symptom and—what is more encouraging—in 4 the symptoms disappeared altogether. In 2 it remained unchanged, while one patient only complained of it after treatment.

We have not ventured to attach too great an importance to the reports of the appearance of the feet at the follow-up examination—again on account of changes in the examiners. Nor did it seem justifiable to place much emphasis on the results of palpation of the arterial pulsation of the feet. However, in 3 patients the changes were convincing and there was also considerable improvement in the results of the *Lewis* function test, and in the postural colour changes, such as pallor of the skin with elevation, and rubor with dependence, of the feet.

Only 1 of the 12 arteriosclerotic cases suffered from pain at rest, and this was unaltered after treatment. Pain at rest often develops after acute arterial occlusion, of which none of our patients showed any evidence.

The vasodilatation test of *Bibbon* and *Landis* makes possible more objective comparisons. In this test the patient holds his hands in water kept at  $44^{\circ}$  C., and the temperature of his feet is recorded. Before the test his lower extremities are exposed to room temperature, which was always about  $20^{\circ}$  C.

Of the 8 patients who improved as a result of the treatment, 7 showed a rise in skin temperature of between 2 and  $9^{\circ}$  C., compared with the maximum temperature previously obtained on the more severely affected foot. In 4 patients the rise was more than  $6^{\circ}$  C., and in 2 the vasodilatation reflex was more brisk, giving a steeper curve. Out of the 4 patients whose condition showed considerable improvement, as already mentioned, 3 gave rises of  $8^{\circ}$ ,  $8^{\circ}$ , and  $9^{\circ}$ , respectively, compared with the maximum temperature measured on the more affected foot before treatment.

As was expected the oscillogram showed no increase in the oscillations. All the 12 patients with arteriosclerosis had

small oscillometric indices for the lower part of the leg, and small oscillations in the upper part of the leg and the thigh. A few patients rises of about 1 in the index, but, as repeated measurements are necessary, and the readings may vary if the cuff is not applied at exactly the same level each time, no conclusions could be drawn.

In 6 of the 12 cases there were small decreases in the oscillometric index; in the other 6 there was no change, which, to say the least, suggests that the organic changes in the vessels were not reduced.

On the other hand, 2 patients, who had improvement in their dyshasia had rather bigger oscillations before treatment than the rest—3 and 2.5 respectively on the lower part of the more affected leg—which might have been considered a good prognostic sign for treatment, whether with procain block or tetraethylammonium bromide. But 2 other patients who showed marked improvement had oscillations of 0 and 1 both before and after treatment, which shows that it is not possible to draw from the oscillometric findings any conclusions on the relative proportions of vasospasm and organic changes in the vessels.

We mention this point particularly, since it is not necessary to assume that the action of the substance on the autonomic nervous system is exclusively a relief of vasospasm. The interruption of reflex arcs through the autonomic ganglia may be of importance also in other ways in patients with peripheral vascular disorders.

The number of unfavourable oscillometric findings before and after treatment with tetraethyl ammonium bromide, including the 8 cases whose condition improved, supports the view that oscillometry is not a satisfactory objective measurement of the condition and of the function in the lower extremities, though it may be useful for a rough localisation of an obstruction in a big artery. This agrees with the opinion of *Allen, Barker and Hines*, who, in their book on peripheral vascular diseases, almost condemn oscillometry as a method



of examination, and do not attach any importance to it as a control test.

In patients with other disorders whom we have treated with tetraethylammonium bromide, sympathetic block or spinal anaesthesia, we have found that the oscillometric index did not rise with effective treatment, and in some cases it was even reduced.

Whether a rise in the skin temperature can be taken as indication of an improved blood-flow through the arterio-venous shunt, or whether there is also an improved blood-flow in the muscles, we have not been able to determine from our investigations; but certainly the reduction of the patients' pain suggests it.

Finally, we should like to report 2 further cases of arterio-sclerotic intermittent claudication. Both showed marked improvement. They were prescribed a protective regimen at the same time as they received the tetraethyl ammonium bromide.

One patient was an official weigher and measurer, aged 58 years. He had worn only carpet-slippers for 7 years, had suffered from cold feet, and before treatment could walk only a few metres. After the second injection of tetraethyl ammonium bromide (6 ml. intramuscularly) he was able to walk well over 3 kilometres in ordinary leather shoes. He no longer suffered from cold feet. A vasodilatation test (see above) showed a satisfactory rise in the skin temperature of his feet, while the oscillometric index showed no improvement after treatment and later the oscillations tended to diminish. One year after treatment he is still satisfied with the result and able to work. (Fig. 1).

The other patient was an infant-school teacher (female), aged 58 years, who before treatment could not walk many steps without cramp in her left calf. Her feet were also cold. 8 months after treatment with tetraethyl ammonium bromide (6 ml. rising to 10 ml.—altogether 10 injections) she is able to walk for an hour provided she does not walk too fast.

The vasodilatation test shows a satisfactory rise in the skin temperature of both feet (Fig. 2). The room temperature

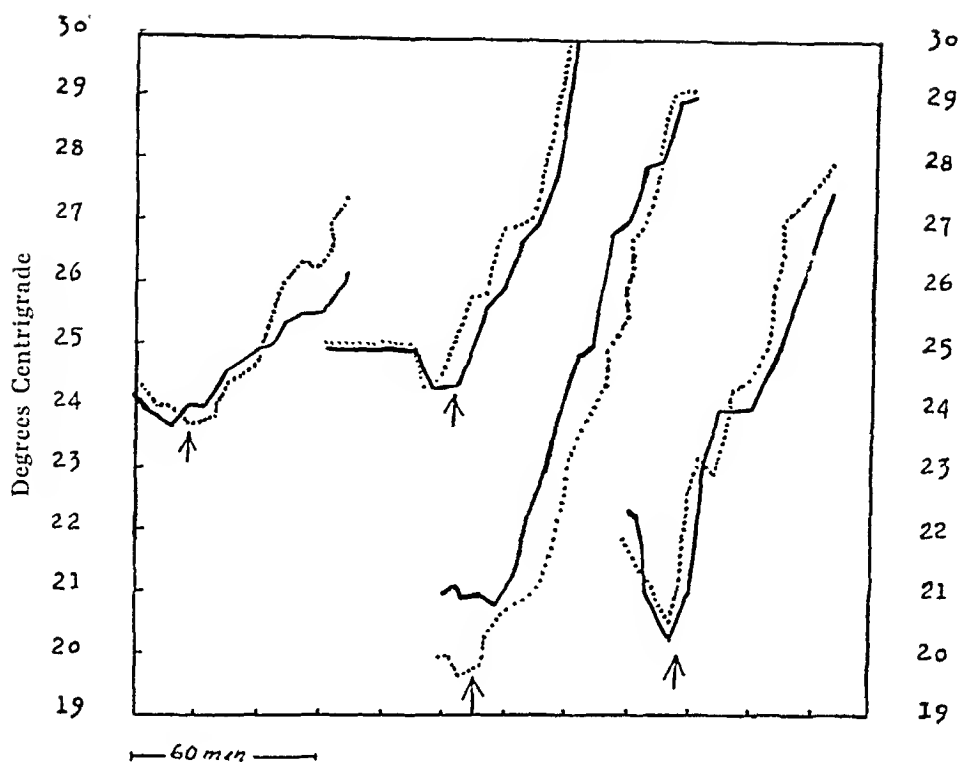


Fig. 1.

Vasodilatation after immersion of hands (indicated by arrow) in warm water. Man aged 54 years with obliterative arteriosclerosis. Skin temperatures of first toe on both sides, — before, 5 days, 3 months and 12 months after treatment (from left).

was higher ( $22^{\circ}$  C.) at the follow-up examination and an attempt was made to cool the feet with a ventilating fan. The maximum value of the oscillations measured on the lower part of the leg was about 3, both before and after treatment.

We have had to prescribe a protective regimen after treatment. This has amounted mainly to general prudence regarding the feet, warm footwear which does not pinch, elevation and postural exercises, and hot and cold bathing, or Hauffe baths.

It would have been desirable, and perhaps also justifiable, to have treated a number of patients with tetraethyl ammonium bromide alone. We think that the substance is a therapeutic victory, and that its effect has been convincing in

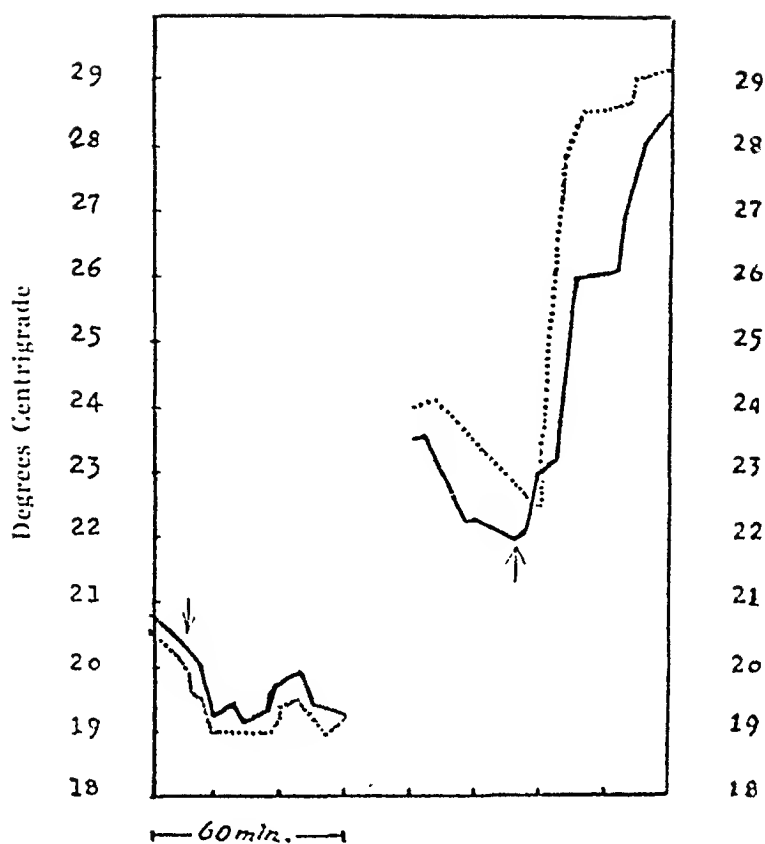


Fig. 2.

Vasodilatation after immersion of hands (indicated by arrow) in warm water. Woman aged 58 years with obliterative arteriosclerosis. Skin temperatures before and after treatment.

several of the patients mentioned. We expect that for some time its use will prove disappointing in many patients in whom the organic changes are more advanced and the spastic element less—in other words, in cases where the reserves of blood supply are small.

On the other hand, this criterium cannot be considered to be universally applicable, since some of our patients felt definite improvement though there was no objective evidence of increased blood-flow through the extremities.

We have encountered no real disadvantages of the dosage which we used, and the patients have felt no discomfort or anxiety with the treatment. On the contrary, some felt re-

markable relief and a pleasant sense of warmth in their legs, even when there was no improvement in the clinical picture.

Most of the patients were out-patients during the final part of the treatment. After injection they were kept in a horizontal position for 30 minutes; they were then allowed to sit up, and we made sure that there was no fall in blood-pressure.

We do not possess any data for comparison with the cases described here, but we think that if the results obtained with tetraethyl ammonium bromide are viewed against the background of lumbar sympathectomy, which is, after all, a comparatively serious operation, they call for further investigation and use of the substance.

#### SUMMARY

12 cases of advanced, well investigated, intermittent claudication of arteriosclerotic origin treated with tetraethyl ammonium bromide are reported.

The dysbasia diminished noticeably in 8 patients, and in 4 there was a remarkable subjective improvement following the treatment. The oscillometric index remained unchanged, but other objective indications of improvement were found, especially an increase in the rise in skin temperature in response to a vasodilatation reflex. The significance of the objective findings are discussed. The results have been encouraging, and call for further investigation and therapeutic use of this substance.

#### RESUME

Communication de 12 cas de malades souffrant de dysbasie avancée et vérifiée, d'origine artériosclérotique traités au tétraéthylammoniumbromide.

Les symptômes dysbasiques ont nettement diminué chez 8 malades et chez 4 on a constaté une sensible amélioration subjective après le traitement.

L'indice oscillométrique ne montrait aucune modification. Par contre, à l'aide d'autres mesures de contrôle, on a constaté une meilleure élévation de la température de la peau à l'épreuve des réflexes vasomoteurs.

L'importance des trouvailles objectives est discutée. Les résultats obtenus ont été si encourageants qu'ils engagent à poursuivre les expériences et à continuer l'administration thérapeutique du produit utilisé.

### ZUSAMMENFASSUNG

Es wird über 12 Patienten berichtet, die alle eine sicher verifizierte arteriosklerotische Dysbasia hatten und mit Tetraäthylammoniumbromid behandelt wurden.

Die Dysbasiebeschwerden nahmen bei 8 deutlich ab, und bei den übrigen 4 kann es nach der Behandlung zu einer sehr wesentlichen subjektiven Besserung.

Der oszillometrische Index zeigte keine Besserung, dagegen fanden sich andere objektive Kriterien einer Besserung, in erster Linie eine erhöhte Temperatursteigerung bei der vasomotorischen Reflexprüfung.

Die Bedeutung der objektiven Befunde wird erörtert.

Trotz des Fehlens eines Kontrollmaterials findet man die Ergebnisse so ermutigend, dass sie zu weiterer Untersuchung und Behandlung mit dem Stoffe auffordern.

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## DISCUSSION

*S. Kiær.*

*A. Langenskiöld:* Tetraethylammonium bromide (Astra) has been used by Dr. Bj. Lindström in the IIIrd Department of Surgery of the Helsingfors University since Dec. 1947. Experience has shown that T.E.A.B. therapy is no substitute for sympathectomy in thromboangitis obliterans. In a case of severe phantom limb pain following disarticulation of the humerus T.E.A.B. had a good effect for 5-6 hours after its injection. The same effect was obtained with a paravertebral injection of novocain. Complete relief was obtained by cervicothoracic sympathectomy.

## ON TREATMENT OF OSTEOCHONDROSIS OF THE SPINE BY SPINAL FUSION

BY

EIVIN HASNER

Osteochondrosis of the spine is characterised radiographically by diminution of the height of one or more intervertebral discs, exostosis formation, sclerosis of the vertebral surfaces in contact with the intervertebral discs, retroposition, and in its early stages also by *Knutson's* vacuum phenomenon.

The present series comprises 100 cases from the Orthopaedic Hospital admitted to the Orthopaedic Hospital, Copenhagen between 1936 and 1946. Only 8 of these cases were treated by spinal fusion.

A modification of *Albee's* method has been used. A thin, elastic bone graft, 6 to 10 cm. long is taken from the tibia, and inserted in the space left when the spinous process has been removed close to the arch. Bone chips taken from spongy bone are placed round the graft. After the operation the patient is laid in a plaster bed and kept there for 3 months. At the end of this period he is fitted with a strong supporting jacket, which is worn for between 6 and 12 months.

All the 8 cases in whom fusion was done, had been treated previously with physiotherapy and conservative orthopaedic treatment. (Plaster jacket, supporting jacket, novocain block).

The patients were: a mechanic, aged 22; a navy, aged 31; a furniture remover, aged 36; and 5 women, aged 27, 32, 33, 35, and 39 respectively and all engaged in house work.

All had marked symptoms and radiographic signs. All complained of pain in the back, localised to the lumbar spine. In 4 cases the pain was so severe that the patients were unable to work. One case (with retroposition) had paraesthesiae.

No case had particularly marked physical signs: there were mild deformities of the spine (kyphosis, scoliosis, straight spine), slight restriction of the mobility in the lumbar region, and infiltrations in the muscles of the back. The patellar reflexes were absent in one case with retroposition.

The radiographic changes were those usually seen in these cases. In all, the height of the L5-S1 and in 2 cases also of the L4-L5 disc, was diminished. All had sclerosis of the vertebral surfaces in contact with the discs. Exostosis formation was seen in 3 cases and retroposition in 2.

Our indications for operation were very rigid, and operation was only resorted to in the most severe cases. In 4 cases the indication was inability to work, in 3, pains so distressing that the patients asked for operation, and in 1 case, retroposition associated with paraesthesiae and absent reflexes.

6 of the patients were symptom-free when followed-up 2 to 6 years after operation. The bone grafts were firmly fused. The osteochondrosis was unchanged. Apart from slightly reduced mobility in the lumbar region the examination revealed nothing of note.

One further case was improved. This was the navy, aged 31 years, who had been unable to work before the operation. After operation he could work, but had lumbar pain, and had to rest for a great part of his off-time. Also his back was rather stiff in the morning. The bone graft was fused. There was no change in the osteochondrosis. There was some limitation of movement in the lumbar spine and there were infiltrations in the muscles of the back.

The furniture remover, aged 36, on the other hand, showed no improvement at the follow-up examination. He had returned to work after the operation, but after 6 months his symptoms recurred and the pain was again severe. Control radiography showed fusion of the bone graft without evidence of fracture. The osteochondrosis was unchanged. There was slightly reduced mobility in the lumbar spine. The muscles of the back were definitely tender.

It is not possible to draw any definite conclusions on the



value of spinal fusion from such a small number of cases. We do believe, however, that fusion is a form of treatment which ought to be used more than has been the practice in this country.

#### SUMMARY

Out of 100 cases of osteochondrosis of the spine treated in at 1. dpt. of the Orthopaedic Hospital in Copenhagen, only 8 were treated by spinal fusion. A modification of Albee's method was used. All 8 cases (5 women) had marked clinical and radiographic signs. The indications for operation were very rigid. The patients were follow-up for 2 to 6 years after operation. 6 were symptomfree; 1 was improved and 1 was unchanged.

#### RESUME

Sur 100 cas d'ostéochondrose de la colonne vertébrale soignés dans le 1<sup>er</sup> Service de l'Hôpital Orthopédique de Copenhague, 8 seulement ont été traités par fusion spinale. La méthode d'Albee modifiée a été utilisée. Les indications pour l'opération ont été très sévères. Les malades ont été suivis entre 2 et 6 ans après l'intervention chirurgicale. Chez 6 aucun symptôme ne s'est manifesté; 1 cas a été amélioré et 1 est resté inchangé.

#### ZUSAMMENFASSUNG

Von 100 im Orthopädischen Krankenhaus zu Kopenhagen behandelten Fällen wurden nur 8 mit Spondylodese behandelt. Die Operationsmethode bestand in einer Modifikation der Albee'schen Methode. In allen 8 Fällen (5 Frauen) waren angesprochene klinische und röntgenologische Symptome vorhanden. Die Indikationen waren sehr streng. Die Patienten wurden 2—6 Jahre nach der Operation untersucht. In 6 Fällen waren die Patienten symptomfrei. In 1 Falle war der Zustand gebessert und in 1 Falle unverändert.

#### DISCUSSION

*Friberg, Berntsen, Bentzon, Novotny, Hasner.*

## FRACTURE OF THE ASTRAGALUS

BY

HANS JENSENIUS

53 cases of fracture of the astragalus and its sequelae have been admitted in the past 12 years to the Orthopaedic Hospital, Aarhus. When doubtful cases and cases in which fracture of the astragalus was only a part—and not the more essential part—of a complicated injury were eliminated, 37 cases remained. Of these, 13 had fractures of the posterior process of the astragalus, while the remaining 24 had fractures of the astragalus proper.

First, a few remarks may be made about the former group—fracture of the posterior process—which is sharply distinct from the main group. This fracture is a small and apparently insignificant injury which may easily be overlooked on the radiographs, unless the examiner anticipates that it may be present. In our material, indeed, it had been missed several times at the first examination before the patient was referred to this clinic. It is, however, by no means an insignificant injury, as is evident from the fact that it had caused discomfort to 8 of the 13 patients for over half a year after the injury, before they were referred to this hospital, while in some of them other, and far more severe, injuries, had healed without sequelae.

So this is a fracture which should not be neglected. It occurs especially in distortion injuries—this was the etiology in 9 out of the 13 cases—sometimes on strong plantar flexion of the foot, not infrequently as a more or less essential com-

plication in fractures of the malleoli and calcaneus. Clinically, 2 symptoms suggest the diagnosis: local tenderness, and either reduced or painful plantarflexion of the foot. Both of these symptoms were recorded in 7 of the 13 patients. A third symptom—pain on flexion of the big toe, due to the course of the tendon of the flexor hallucis close to the posterior process—is more theoretical; it was not recorded in any of the cases.

On radiography, the diagnosis was obvious in some cases, and very doubtful in others, especially in those of long standing. In particular the occurrence of os trigonum as a separate bone may make the diagnosis difficult,—though this is, perhaps, of minor practical importance, as an os trigonum exposed to a distortion injury may give the same indication for excision as fracture of the posterior process.

This radical treatment of the fracture—excision—was offered or advised in many of these cases, but it was performed only three times. The remaining cases were treated conservatively with plaster, novocaine injection or orthopaedic footwear. The cases have not been followed-up.

Before turning to the main group of the material, the 24 cases of fracture of the astragalus proper, I shall briefly mention the characteristic features of the astragalus that give the fractures of this bone their particular character:

1. The thick shape of the bone, its position between the other bones and its lack of muscle insertions explain the relative infrequency of its fracture. According to *Eiken* (1917), its incidence compared with that of fractures of the calcaneus is 1:10.

2. About three-fifths of its surface is covered with cartilage distributed on 7 articular surfaces, and a fracture line must nearly always involve one or more articular surfaces, so that even slight displacement will result in severe arthrotic changes.

3. The same feature makes the nutrition of the bone easily impaired, so that a fracture involves considerable risk of necrosis, especially of the body. Even though the numerous

ligamentous attachments are all accompanied by small vessels, by far the greatest blood supply is received through the neck of the astragalus—as can be seen in injection preparations. Therefore, any fracture through the neck involves considerable risk of necrosis of the body, and this necrosis is almost inevitable if, at the same time, the posterior ligamentous attachments are torn—as when there is fracture of the neck of the astragalus with backward displacement of the body. The frequency of necrosis in these two forms of injury is given by *Walson-Jones* to be 50 % and 100 %, respectively.

4. Finally, the central position of the bone, and its importance to the structure of the foot is a reason why deforming fractures may cause pronounced malpositions of the foot—more often a varus, but sometimes a valgus position.

It must be mentioned here that the present material consists almost exclusively of the sequelae of fractures which were treated primarily elsewhere. Only 3 cases were recent, 9 had occurred up to 1 year, and 11 over 1 year before—with 13 years as maximum. This means that the material is selected, in that it consists of cases with sequelae who have applied to the clinic, but I think that the fact that we have received relatively many cases of this rare fracture signifies that it is a serious one.

I have tried to divide the 24 cases into several groups by comparing the data on the trauma with the type of fracture seen on the radiographs, and I think it is practicable to classify most of the fractures with a fair degree of certainty according to the way in which they occurred. But I must stress that the fractures are so various that any classification must in some degree be artificial. In 10 cases I found that the fracture occurred with traumatic dorsiflexion, in 5 cases with traumatic inversion and inflexion of the foot, in 4 cases with direct trauma—and finally there are 5 cases in which I was not able to determine the trauma.

1. Accordingly, in the first and largest group, comprising 10 cases, the trauma was either strongly dorsiflexing or acted on a dorsiflexed foot, and a fracture of the neck with or with-

out dislocation occurred. Of the 10 fractures 6 took place on a fall from a height, in which we have to assume that the foot hit the ground in dorsiflexion. According to *Böhler*, this is the ordinary mechanism of fractures of the astragalus, whereas fractures of the calcaneus are said to arise in falling



*Fig. 1.*

Simple fracture of the neck of the astragalus with the fracture angle open towards the dorsum. Sclerotic changes in the trochlea.

on the foot in neutral position. With the third possibility—traumatic injury to the foot in plantar flexion—the fracture is said to arise posteriorly in the astragalus by impact with the posterior margin of the tibia. Such a trauma is of rare occurrence, however, and therefore the corresponding fracture

is rare; our material, however, includes one typical case of this kind.

In the more common injury occurring in dorsiflexion, the anterior margin of the tibia is thought to be driven down like a wedge into the posterior part of the neck of the bone, sometimes into the anterior part of the trochlea, resulting in a transverse fracture, most often with an angle opening to the dorsum. However, according to the theory which was originally advanced by *Ombredanne* and was supported by *Eiken* and others, the fracture occurs normally as a simple flexion fracture, the body being fixed in the malleolar fork while the head is displaced dorsally, and the tibia plays no part in its production. But when—as seen in Fig. 1—the anterior margin of the tibia is also injured, the former origin seems more probable.

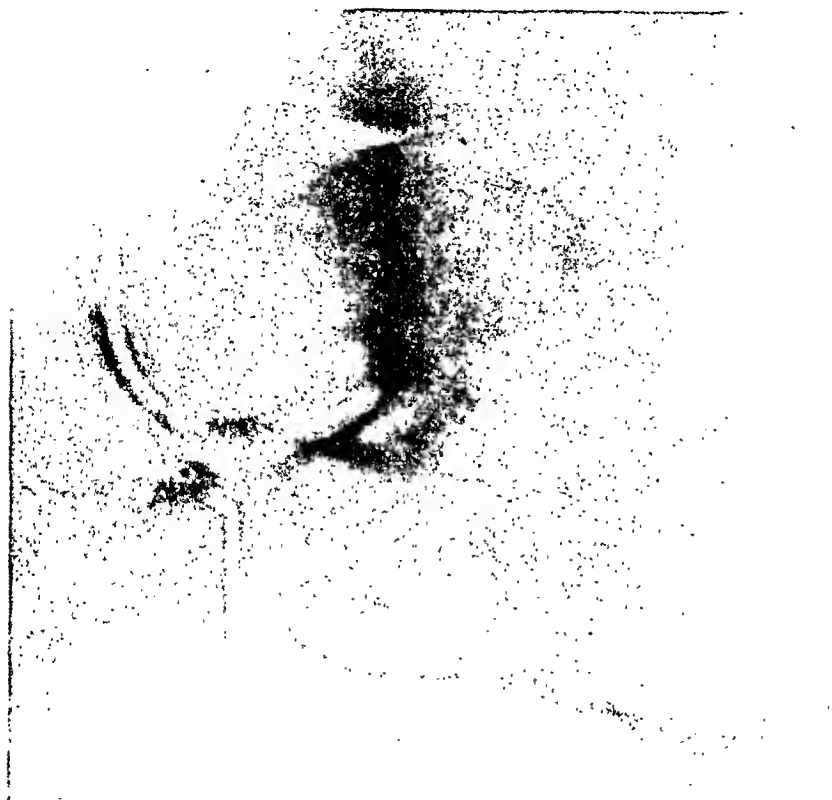
The patient was a woman who had fallen off a load of hay 4½ months before admission. There is a simple fracture of the neck of the astragalus with the angle open dorsally. In addition, sclerotic changes indicating nutritional disturbance can be seen in a small part of the trochlea.

This relatively simple fracture after dorsiflexing trauma was found in 8 of the 10 cases. Trauma acting further in this direction causes, in addition, forward dislocation of the distal fragment + the entire subtalar foot, including the calcaneus. Presumably such a dislocation had occurred in some of these 8 cases, but had been reduced immediately after the injury, so that it was not present on admission. It was mentioned in the history in 2 cases. One case, however, was hospitalized immediately after the injury, and it shows several interesting features:

The patient was a mason, 25 years old, who fell off a church tower. The radiograph is shown in Fig. 2: Fracture of the neck of the astragalus with about 2 cm. forward displacement of the distal fragment + the foot. The body is in the malleolar fork but appears to have rotated round a sagittal axis. Closed reduction was impossible, and at operation this was explained by the fact that both the peroneal tendons had been



fragment out of the malleolar fork. Such a dislocation depends on injury to the attachments of the posterior ligaments simultaneously with the fracture, and, presumably, on the fracture being posterior to the lig. interosseum, so that the corpus



*Fig. 3.*

Same case as Fig. 2. Picture taken 4½ years after the reduction. Compression of the sclerotic body and arthrosis.

fragment can be dislocated almost freely. Our material also includes one case, which was treated immediately. The accident occurred in an uncommon but quite characteristic way:

The patient was a rescuer, 28 years old. While working with a crane car, the crane was overloaded and he tried to keep the front of the car down by bearing down on the fender. Then the wire of the crane broke suddenly and the front end of the car came down, with the fender strik-



ing his bent leg just above the knee on the femur, which did not break, but transmitted the impact to the foot, in dorsiflexion. This typical injury (Fig. 4) resulted; fracture of the neck of the astragalus with backward dislocation of the body, which is rotated 90 degrees round both a frontal and a sagittal axis. Operative reduction was easy after

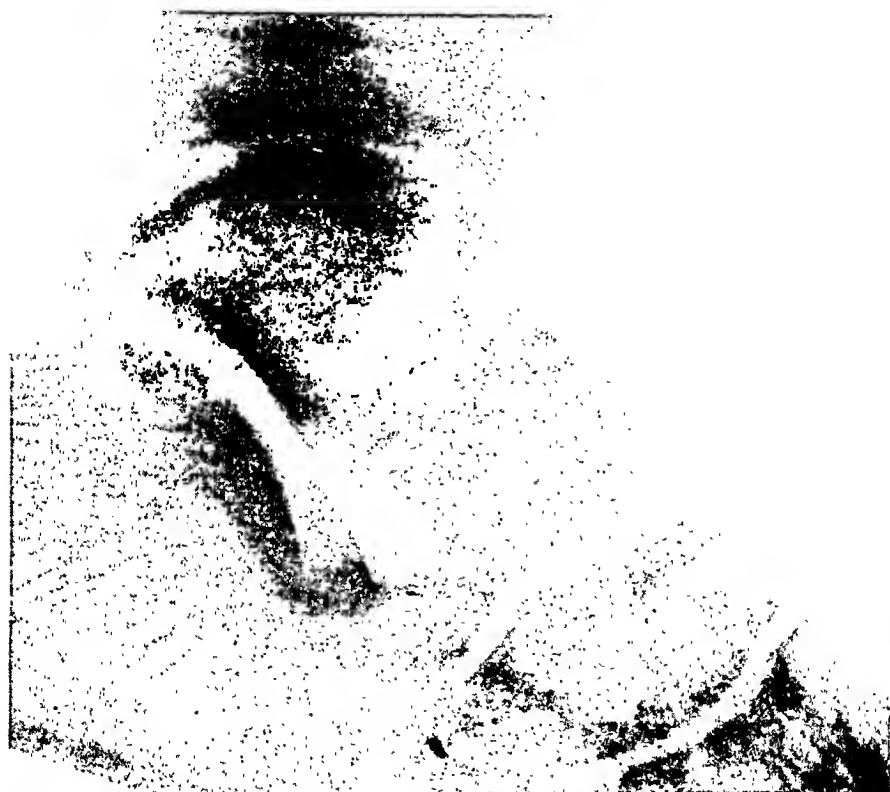


*Fig. 4.*

Fracture of the neck of the astragalus with backward dislocation of the body fragment.

temporary division of the Achilles tendon (Fig. 5) but — one might say, of course,—necrosis of the body with increasing density of the bone radiographically occurred. (Fig. 6.) After one year the sclerosis is decreasing. The joint space is narrowing towards the tibia, but there is no sign of arthrosis and no compression. This patient walked in a walking plaster for 20 weeks after the accident.

II. This group comprises 5 cases in which the fracture occurred with inversion and in flexion trauma. Usually this type of trauma causes distortion and dislocation, both subtalar and in Chopart's joint, but often the dislocation is accompanied by fracture of the astragalus, and I think that these



*Fig. 5.*

Same case as Fig. 4, immediately after operative reduction.

5 cases should be considered to have occurred in this way, though usually the dislocations were not seen here in the hospital. The traumas were of various kinds: falling from a height, motor accident, falling off a bike, stumbling while playing, faulty jumping; in several cases the fracture caused compression of both the head of the astragalus and the os naviculare.

Fig. 7 gives an example of this injury: the patient was run over by a wagon 9 months before admission; there is marked compression of the head of the astragalus and medial dislocation of the navicular bone.

*III.* In the four cases in this group there was a history of direct trauma. In 3 of the cases a heavy object fell down on



*Fig. 6.*

Same case as Fig. 4. Photo taken 4 months after the reduction. Pronounced sclerosis of the body, but no compression. Normal joint surface.

the foot, producing an open fracture in 2; the fourth case was due to a gun-shot injury. In all, the fracture was untypical, involving chiefly the body.

*IV.* Finally, there are 5 cases which I have not been able to place in any definite group from the available data.

It will be seen that this etiological classification corresponds roughly and with several exceptions to an anatomical

grouping, the dorsiflexion traumas involving especially the neck, inversion traumas the head, and direct traumas the body.

It is the protracted sequelae of fractures of the astragalus which brings the patients to seek orthopaedic treatment. There are three main sequelae: necrosis of the body with compression, arthrosis, and deformity of the foot. The reasons



*Fig. 7.*

Inversion fracture. Compression of the head of the astragalus and medial dislocation of the navicular bone.

why these three sequelae are frequent in fracture of the astragalus have already been discussed.

*Necrosis:* 5 cases presented radiographic signs of necrosis of the body, and in 2 necrosis was the direct cause of compression of the body. Further, this compression may be the cause of arthrosis as well as of deformity. It should be the aim of the treatment to prevent it by means of prolonged protection from weight bearing. We have seen one case with compression after 12 weeks protection from weight-bearing, and another case without compression after 20 weeks protection, which indicates perhaps how long it should be continued.

*Arthrosis:* Of the 24 cases 11 showed radiographic and

clinical signs of arthrosis on admission. In 6 the arthrosis was most marked in the talonavicular joint; in 5 in the talocalcaneal joint, and in one of these it was also marked in the talocrural joint. Arthrosis has appeared as early as 2 months after the accident. In 6 cases it was found on admission of the patient within one year after the accident; and the longest time for its appearance was  $4\frac{1}{2}$  years. In some cases, rather slight displacement of the joint surfaces has caused severe arthrosis, while, conversely, severe injuries may give lesser sequelae, especially if they cause spontaneous ankylosis. Arthrodesis has been considered for all these 11 cases of arthrosis: it was performed on 7 patients—6 times as a subtalar arthrodesis, once as a panarticular arthrodesis.

*Deformity:* The deformity after poor union of a fracture of the astragalus is generally said to be a pes equino-varus, a traumatic club-foot. However, valgus deformities are also seen in some cases. Marked deformity was found in 13 of our patients: varus in 9, valgus in 4. Valgus deformity was found after fracture of the neck with dorsal opening of the angle. With this deformity, on the whole, the astragalus has a similar form as in pes plano-valgus with a very wide inclination angle, so that the valgus deformity is easily explained. (cf. Fig. 1.) This was the pathogenesis in 3 of the 4 cases, while the fourth patient had no deformity of the astragalus, but in addition to the fracture he had had a subtalar dislocation, which probably caused insufficiency of the foot.

Of the nine patients with varus deformity 5 had compression of the body, either as a direct result of the fracture of the body, or secondary to its necrosis. If the patient is first examined only long after the accident it may be impossible to decide which is the case. When the injury to the body leads to a varus deformity it is probably due to the fact that somehow the compression has mainly occurred in the medial part of the corpus. In 2 other cases the varus deformity appeared after an inversion trauma. In 2 cases the reason for the varus deformity was somewhat obscure.

The present material gives no occasion to discuss the treat-

ment of the fresh fracture. In the treatment of its sequelae, arthrodesis holds a prominent position. As already mentioned, this material is made up chiefly of severe consequences of the fracture, and there was no indication for an arthrodesis in only 7 out of the 24 cases. In 8 cases, arthrodesis has not yet been performed for various reasons; it has been done in 9,—as subtalar arthrodesis in 8 and panarticular in one. The indications have been arthrosis or faulty position or, most often, both. Varus deformity has been a contributory indication in 6 cases, valgus in 3, and arthrosis in 7.

We have obtained information on the results of the operation, either at out-patient examinations or from written questionnaires answered by the patients from 3 to 8 years after the operation. On the basis of these data I have estimated the results as being good or fair in 5 cases and unsatisfactory in 4. All the patients, however, are able to carry on their previous occupations, but those who are termed unsatisfactory have reduced working capacity and have to wear hand-made footwear. Reexamination showed that in 3 a considerable degree of varus deformity was the cause of the permanent disability. So, I think that this material justifies the conclusion that arthrodesis is indicated in severe sequelae of fracture of the astragalus, and that it may be expected to have a good result, provided that a possible varus deformity is fully corrected by the operation. The good prognosis associated with the arthrodesis should lead to the following principle: Excision of the astragalus, which used to be recommended in all severe fractures of this bone, should be avoided as far as possible.

#### SUMMARY

A series of cases of fractures of the astragalus—from the Orthopaedic Hospital in Aarhus—is presented; it consists chiefly of cases with severe sequelae to the fracture, and includes only 3 recent cases.

There are altogether 37 cases; the posterior process of the

astragalus was fractured in 13, and the astragalus proper in 24.

The fractures are classified according to their origin, and examples of the various forms are given.

Mention is made of the late sequelae: necrosis of the head, arthrosis, and deformity.

The writer emphasises both the importance of prolonged protection from weight-bearing on the fresh fracture in cases with necrotic changes in the body in order to avoid compression, and the value of arthrodesis in the treatment of sequelae.

### RESUME

Une série de cas de fractures de l'astragale — de l'Hôpital Orthopédique d'Aarhus (Danemark) — sont rapportés: il s'agit principalement de séquelles de fractures, 3 cas seulement étant récents.

Les observations portent sur 37 cas au total; fracture de l'apophyse de l'astragale 13 cas et de l'astragale proprement dite 24 cas.

Les fractures ont été classées d'après leur origine et il est donné des exemples de leurs formes variées.

Il est fait mention des séquelles tardives: nécrose de la tête de l'astragale, arthrose et déformité.

L'auteur souligne à la fois l'importance qu'il y a à protéger de tout poids pendant très longtemps la fracture fraîche quand il y a des modifications nécrotiques du corps de l'astragale, afin d'éviter toute compression, et la valeur de l'arthrodèse dans le traitement des séquelles.

### ZUSAMMENFASSUNG

Eine Reihe von Fällen von Talusfrakturen — aus dem Orthopädischen Krankenhaus in Aarhus — werden mitgeteilt; das Material besteht hauptsächlich aus Fällen mit Sequelae der Fraktur und enthält nur 3 frische Fälle.

Es umfasst insgesamt 37 Fälle; der Processus posterior

tali war in 13 Fällen gebrochen und der Talus selbst in 24 Fällen.

Die Frakturen werden nach ihrer Ursache eingeteilt, und für die verschiedenen Formen werden Beispiele gegeben.

Die Spätfolgen werden erwähnt: Caputnekrose, Arthrose und Deformität.

Verfasser betont die Bedeutung einer prolongierten Immobilisierung und Entlastung der frischen Fraktur in Fällen mit nekrotischen Veränderungen des Corpus zur Vermeidung einer Kompression sowie den Wert einer Arthrodesse bei der Behandlung der Sequelae.





## BACK PAIN IN RELATION TO THE NERVE SUPPLY OF THE INTERVERTEBRAL DISC

BY

GUNNAR WIBERG

The problem of the genesis of pain in the back is as interesting as it is difficult. In view of the remarkable frequency of the different pains in the back, it is surprising that the problem has not been more studied than it has. But this becomes perhaps more understandable, when one approaches the subject more closely and discovers all the difficulties connected with this problem.

Although pain occurs in all parts of the back, it is most common in the lumbo-sacral region, and I will confine my remarks to this region. Our recently acquired knowledge of sciatica and disc prolapse may shed some light on the subject and is a further reason for confining discussion to this part of the back.

The pain may arise from a number of tissues. Muscles, ligaments, intervertebral discs, intervertebral joints, and perhaps even the bone itself may be the origin of the pain. An earlier much advocated theory proposed a myalgic origin for the pain, and I need only mention *Folke Lindstedt's* big work on the subject. We have, however, gradually abandoned this explanation, which, though the possibility of a muscular origin cannot be entirely excluded, now seems less likely. For instance, night pain may occur and even waken the patient, and it does not seem likely that a resting muscle would cause such pain.

*Leriche* and *Jung* were able, in a number of cases of back pain and reduced disc space, to make the pain disappear and the disc space increase by the injection of local anaesthetic

round the vertebral bodies. They considered that this would be satisfactorily explained if the pain arose from the ligamentous coverings of the disc, and caused a contracture and narrowing of the disc. They do not discuss whether the pain should be regarded as arising directly from the nerve fibres in the ligament, or whether its real origin was the muscle contracture due to the irritation.

Meanwhile, it seems that a study of the nerve supply to this part of the back might be of some value in this question, and *Luschka* and *Hovelaque* and, more, recently *Roofe* have studied this aspect.

*Luschka* was the first to demonstrate a special nerve which arose just distal to the spinal ganglion, joined a sympathetic branch and passed into the spinal canal where it split up into branches. He called it the sino-vertebral nerve. Some of the end branches ended at the base of the neural arch, and he believed that they probably entered the bone. Other branches followed the vessels, and others were distributed in the space between the dura and the ligaments of the spinal canal.

*Hovelaque* made similar anatomical investigations, but came in part to different conclusions. He, however, gave no information about the part of the back, which is in this connection of most interest, namely, the lumbar region; one may perhaps assume that this region does not differ from the thoracic and sacral regions. *Hovelaque*, like *Luschka*, believes that the sino-vertebral nerve is formed by a cerebro-spinal and a sympathetic root, although sometimes there may be two roots of the same type. The roots either unite early, so that a single stem passes through the intervertebral foramen, or later, within the spinal canal. The common stem, when well inside the canal, breaks up into end branches, which end as fine fibres in the dura, the outer surface of the vertebral bodies, the ligaments and the vessels. *Hovelaque* did not confirm *Luschka's* findings that the sino-vertebral nerve divided into proximal and distal branches which anastomosed with the nerve above and below.

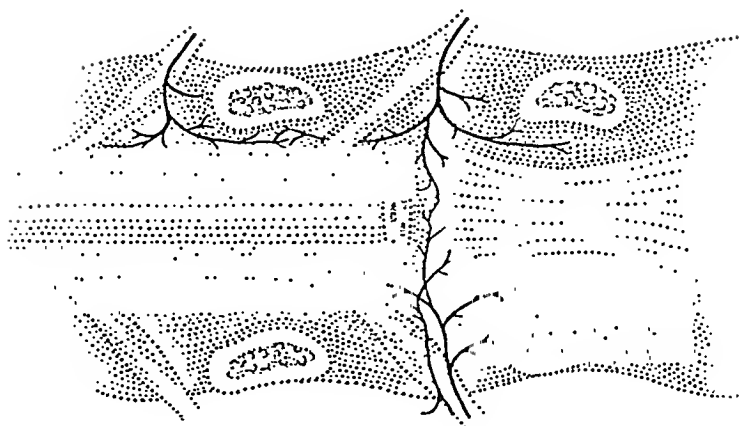


Fig. 3.

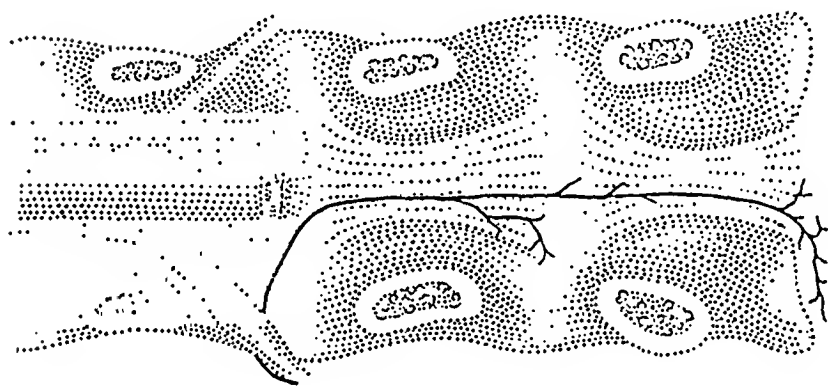


Fig. 2.

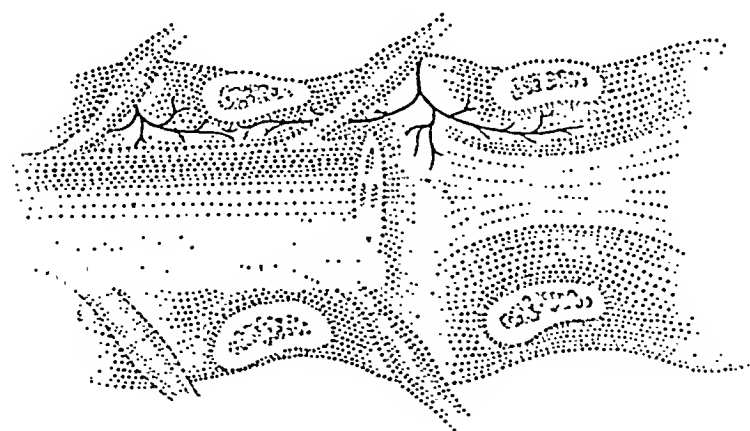
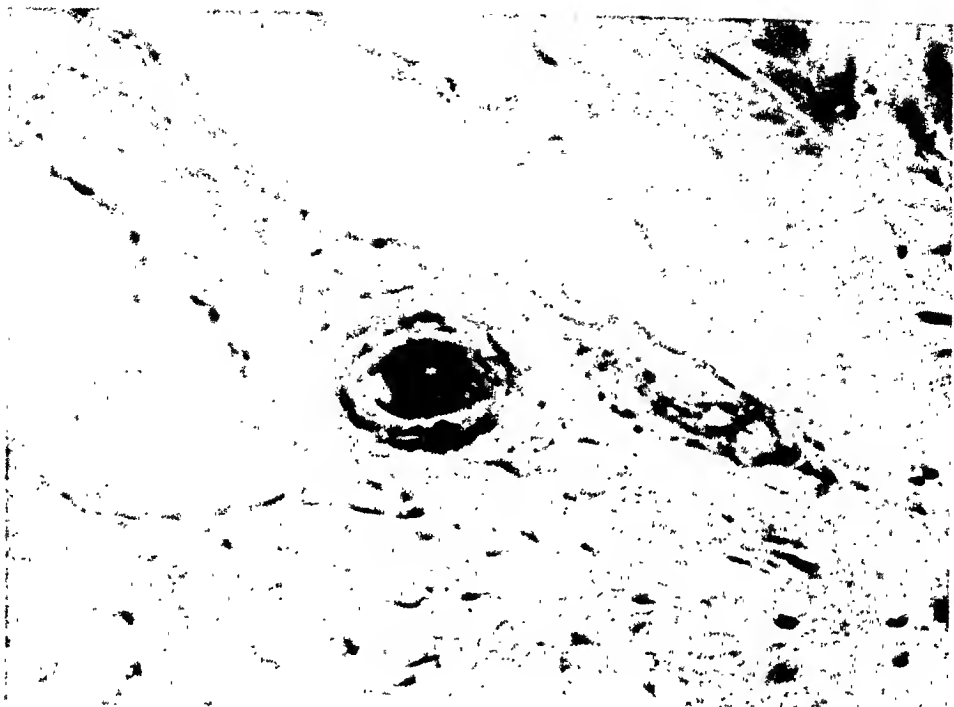


Fig. 1.

The course and division of the recurrent nerve (sino-vertebral nerve) according to  
1. Luschka. 2. Roofe. 3. The author.



*Fig. 4.*

Longitudinal section of nerve fibre in outer layer of the ligamentous covering of the intervertebral disc. (silver staining according to *Gross-Schultze*).

The American worker, *Roofe*, (1940), found that a recurrent branch was given off just distal to the ganglion, ran into the spinal canal through the intervertebral foramen, and passed down as a main stem to be distributed in the ligaments one or two vertebral levels below its entrance.

In order to form my own opinion on these macroscopic findings I have dissected a number of specimens of the lower lumbar vertebrae and sacrum. The posterior skeletal parts (the spinous processes, the vertebral arches and the intervertebral joints) were removed, and the dural sac and the nerve roots leaving it were exposed. It was found that it was easier to make the dissection on quite fresh material, which had not been hardened in formalin, and 14 peripheral nerve roots and spinal ganglia have been dissected out in this way. It was often difficult to distinguish between the very fine



Fig. 5.

Transverse section of nerve in the ligamentous covering of the intervertebral disc. (silver staining according to *Gross-Schultze*).

nerve fibres and the vessels, and in some instances their real nature had to be determined later histologically. Usually I found that a nerve ( $\frac{1}{2}$ -1 mm. thick) arose distal to the ganglion, passed back through the intervertebral foramen, and immediately divided in the spinal canal into end branches, which ran toward the base of the spinous process and the ligamentum flavum. In some cases there was also a smaller nerve arising distal to the ganglion, which joined with a branch from the sympathetic. This combined nerve also passed through the intervertebral foramen into the spinal canal, where it soon broke up into branches to the ligamentous tissues, particularly in the neighbourhood of the disc.

The dissection of the fine terminal branches in the skeleton is sometimes particularly difficult, and I think this is the reason for the different findings of different workers. It seems at any rate to be certain that a recurrent branch arises distal

to the ganglion and is joined by a branch from the sympathetic chain (in most cases). The branching of the nerve may vary considerably, and the different branches may join each other.

It was necessary to supplement these macroscopic findings by microscopic examinations, paying particular attention to the disc and the ligamentous connections between the vertebral bodies.

✓ *Jung and Brunschwig*, two of *Leriche's* pupils, investigated the intervertebral disc and the nerve supply of the surrounding ligaments. They came to the conclusion that the nucleus pulposus and annulus fibrosus contain no nerve tissue, but that there are nerves in the surrounding fibrous ligaments. The anterior border of the disc would have a particularly plentiful nerve supply, i.e. in the attachments of the anterior longitudinal ligament to the annulus fibrosus, while the lateral, and even more the posterior, borders would be less well supplied. The nerve branches always appeared to end in the inner part of the connective tissue layer of the ligament, and these workers were not once able to find nerve branches in the outer layer of the annulus fibrosus. They also thought that the nerves contained sympathetic fibres.

My own histological studies on the innervation of the intervertebral discs were made on specimens taken from adults and from full term foetuses, the lumbar discs being examined. In the first series 6 discs were sectioned. After fixation in 10 % formaldehyde, frozen sections 20-30  $\mu$ m. thick were made. The sections were silver-stained according to *Gross-Schultze's* method, which stains the axis cylinders of the nerves. In 2 of the 6 cases, nerve fibres could definitely be demonstrated; in one there was a longitudinal and in the other a transverse section of the nerve fibre. In both cases the nerve lay in the outer part of the ligament. No nerves were seen in the annulus fibrosus or nucleus pulposus. In 6 adult cases the vertebral bodies and their ligaments were also examined, and in these cases the specimens were decalcified after fixation in 10 % formaldehyde, embedded in paraffin

wax and stained by *Bodian's* method. No nerves were seen in the vertebral bodies, or in the ligamentous coverings.

This part of the investigation was particularly difficult, since the decalcification appeared to be a very harsh treatment for the nerves' delicate structure. For this reason, the series of foetal preparations is being studied, in the hope that more positive findings will be obtained after the less harsh treatment which they require. These investigations are not yet complete.

It is certainly desirable to supplement these examinations of the macro- and microscopical nerve supplies of the intervertebral disc by studies of living material, and one would expect operations for disc prolapse to provide a satisfactory opportunity. It should be possible to discover by palpation how pain originates in the different parts of the back. There are, however, practical difficulties, since palpation affects more than one part (intervertebral disc, vertebral body, nerve root, ligament, intervertebral joint, etc.). It is not possible to know whether palpation of one part, e.g. the surface of the vertebral body, may not cause pain from the intervertebral disc, due to movement.

However, during the last 3 years, various tests have regularly been made at operation, in spite of these drawbacks; and generally speaking I can agree with *Spurling* and *Grantham's* findings, that palpation of an intervertebral disc causes pain in the back; and I think that the results of palpation can even be more exact. The operations are now performed under a local anaesthesia (confined to the skin, subcutaneous tissues and muscles), which has no action on the nerve roots; this can be demonstrated by palpation of the root, which always causes acute root pain.

Touching the ligamentum flavum caused no sensation; this is well known to all surgeons of disc prolapse, as the ligament can be divided without any anaesthesia. In most subjects, firm pressure on the posterior surface of the vertebral body caused no pain, and in the few, among 200 operated cases, who felt pain, it could be explained as arising from a



change in the relative positions of the vertebral bodies causing pain from the intervertebral disc. On the other hand, touching the disc itself caused pain of lumbosacral distribution in nearly all cases, and the patients stated that it felt as if the pain was inside the back. In some cases it was possible to palpate the disc without a preliminary anaesthetic injection of the nerve root, but in most the root had to be anaesthetised before the posterior part of the disc could be exposed for palpation. No difference between the results of these two groups was found, and in view of our knowledge of the recurrent nerve branches this must be interpreted as evidence that the disc has a nerve supply in addition to the recurrent nerve, since no pain could pass through the anaesthetised root. There are two possible explanations; either, in accordance with *Roofe's* studies, a branch of a recurrent nerve supplies lower discs, or the pain is transmitted by the recurrent nerve of the opposite side. Naturally, one does not often have the opportunity to extend the examination and anaesthetise most of the nerve roots on one or even both sides. In some cases, however, I have been able to do this, and have tried to produce pain when two roots on the same side have been anaesthetised. Pain could still be elicited from both the segmental intervertebral discs, and no conclusions can be drawn. The explanation may be one of those suggested above, either the recurrent nerve branch supplies the intervertebral disc two vertebrae lower, or the recurrent branch from the opposite side transmits the pain.

In some cases an elevator was inserted into the intervertebral disc after the prolapse had been removed, to find whether touching the surface of the vertebral body facing the disc caused pain; the result was always negative.

Although these anatomical, histological and clinical investigations do not form a definite proof that pain in the back arises in the intervertebral disc, or, more accurately, in its ligamentous coverings, one may venture to say that there are considerable points in favour of this hypothesis. Disc degeneration causes a certain instability between the vertebrae, and thus there arises the possibility of strain on the ligamentous

covering of the disc. Distraction, which is impossible under normal conditions, may occur, causing pain in the nerves in the ligament.

In this connection I should like to put forward a further idea, which may perhaps be regarded as support of this conception.

The condition is well-known in which a patient with acute lumbago, a few hours, or perhaps a few days, later gets a true sciatic pain which is found at later operation to be due to a prolapse of the intervertebral disc.

It is natural to seek a common explanation for the lumbago and the sciatica, and it remains only to ask whether the lumbago is not also explained by the disc prolapse.

*Andersen* suggested that when the annulus fibrosus ruptures under strain, bleeding occurs into the tissues and causes pain. *Waldenström* has suggested that when a part of the disc passes through a rupture in the annulus and reaches the surface, it first meets the nerve fibres in the periphery of the root, and it is the irritation of these which causes the lumbago. If the rupture extends further the deeper fibres within the root are compressed, and sciatic pain results.

For myself, I think that it is conceivable that the ruptured disc which is found in disc prolapse from whatever cause (awkward movement, severe strain), shifts forward to the ligamentous coverings and presses on this nerve-containing tissue; this causes a severe pain in the form of an attack of lumbago. If the disc shifts still further, and reaches the nerve root, sciatic pain also develops.

Thus, this conception of the origin of the pain from the ligamentous covering of the disc would explain both the chronic lumbar pain of insufficiency, and its development into a more acute type of lumbago. If we presume this so far hypothetical explanation to be correct, the genesis of back pain is found to be unified.

## SUMMARY

The author has dissected preparations of the lumbar and sacral spines, and, like *Luschka*, *Hovelaque* and *Roofe*, was able to confirm the existence of a nerve which arises distal to the ganglion, passes back through the intervertebral foramen into the spinal canal and there divides up. The presence of nerves in the intervertebral disc has also been investigated microscopically, and fibres were found in the ligamentous coverings of the disc. Examinations made at disc operations showed that pain could be caused by touching the surface of the disc, but not by touching the surfaces of the vertebra or the ligamentum flavum. Like *Leriche* and *Jung*, the author believes that it is conceivable that pain arises from the ligamentous covering of the discs.

## RESUME

L'auteur a pratiqué la dissection de préparations de la colonne vertébrale lombo-sacrée et comme *Luschka*, *Hovelaque* et *Roofe*, il a pu percevoir un nerf s'éloignant du ganglion et revenant par le trou de conjugaison dans le canal rachidien pour s'y diviser en plusieurs branches. Il a procédé par ailleurs à l'examen microscopique des nerfs qui apparaissent dans les ménisques et il a pu découvrir des filets dans le tissu fibreux recouvrant le disque. Des examens partiqués à l'occasion d'opérations de ménisques ont prouvé qu'il est possible de déclencher une douleur par la palpation de la surface du ménisque et non par la palpation des surfaces du corps de la vertèbre ou du ligamentum flavum. Comme *Leriche* et *Jung*, l'auteur estime qu'il est probable que le déclenchement de la douleur provient du tissu fibreux recouvrant les ménisques.

## ZUSAMMENFASSUNG

Der Verfasser hat Sezierungen am Lumbosakralrücken vorgenommen und konnte, ebenso wie *Luschka*, *Hovelaque* und *Roofe*, einen distal vom Ganglion abgehenden Nerven

feststellen, der via foramen intervertebrale in den Spinalkanal zurückkehrt und sich dort verzweigt. Weiterhin wurden mikroskopische Untersuchungen über das Vorkommen von Nerven in den Zwischenwirbelscheiben durchgeführt. Nervenfasern konnten in den ligamentösen Bekleidungen der Scheiben nachgewiesen werden. Untersuchungen im Zusammenhang mit Diskusoperationen haben erwiesen dass eine Schmerzauslösung durch Berührung der Scheibenoberfläche aber nicht durch Berührung der Wirbeloberfläche oder lig. flavum geschehen kann. Verfasser ist der Meinung ebenso wie *Leriche* und *Jung*, dass die Schmerzauslösung wahrscheinlich von der Ligamentbekleidung der Zwischenwirbelscheiben geschieht.

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## ANATOMICAL AND CLINICAL STUDIES ON LUMBAR DISC DEGENERATION

BY

STEN FRIBERG and CARL HIRSCH.

### A N A T O M Y

Abnormal mobility between two vertebrae had previously been observed both at autopsies and operations. In 1944 Knutsson showed that, in certain cases, hypermobility between two lumbar vertebrae could be demonstrated roentgenologically, that in bending forward there was ante-position and in bending backwards retro-position of the cranial to the caudal vertebra. This abnormal mobility which we have called instability of the vertebrae was observed both with other roentgenological signs of disc degeneration and as an isolated phenomenon. When it occurred alone, Knutsson regarded it as an early sign of degeneration of the intervening disc. Patho-anatomically this has not yet been confirmed.

We have made a patho-anatomical study of the lumbar discs with special regard to cases with radiographic signs of degeneration and to cases where instability occurred as an isolated phenomenon. The material consists of 100 spines i.e. 500 lumbar intervertebral discs from autopsy cases. The age variation is shown in fig. 1 below. The spines were taken from patients who had died from e.g. ulcer, trauma, circulatory disturbances etc.; those dying from infection or metastatic tumours were excluded.

The material was selected. We tried to have cases from all age classes but we were mainly interested in those between the ages of 21 and 50 years. The lumbar spine was dissected

1-10 years	9
11-20 "	4
21-30 "	21
31-40 "	17
41-50 "	21
51-60 "	12
61-70 "	12
71-80 "	3
81-90 "	1
<hr/>	
100 cases	

*Fig. 1.*

The table shows the number of post mortem cases in each age group.

out with the sacrum and fixed in a vice, and as soon as possible after death, in most cases after a few hours, at room temperature, the preparation was flexed and extended without force and X-rayed in the different positions. After a short period of formalin fixation the intervertebral discs were removed by horizontal section and macrophotographed. Microscopical examinations were made on the material:

Radiographic changes	Number of spines	L1	L2	L3	L4	L5	Number of intervertebral discs
normal radiographs	46						
instability	15			1	12	4	17
disc degeneration	17	2	3	4	9	11	29
vacuum phenomenon	10		1	1	5	3	10
spondylosis deformans	20						
spondylolisthesis	2					2	2
osteoporosis	1						
Mb. Bechterew	1						

*Fig. 2.*

The frequency of the different changes seen on the radiographs.

Roentgenological signs of disc degeneration, i.e. reduced disc space, osteophytes and sclerosis, were observed in 29 spaces (17 cases), and instability in 17 spaces (15 cases): 12 of these were in the fourth disc.

The nucleus pulposus shows regressive changes quite early (Schmorl and others). With increasing age the fluid content decreases, the fibrous structure increases, and the delimitation from the annulus becomes less marked. It seems that these changes should be regarded as lying within the

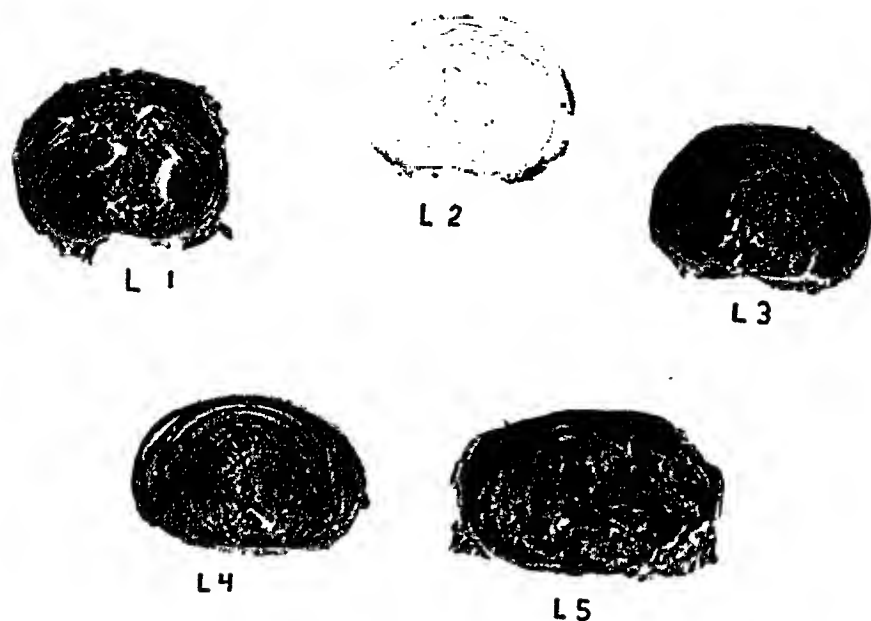


*Fig. 3.*

Radiograph of case 56. The disc space between L1 and L2 is rather narrower than is normal. Slight osteophyte formation on the lower anterior border of L1. The L2-L3 space is normal. L3 vertebra is slightly retroposed to L4, and there is a small osteophyte on the upper anterior border of L4. L4-5 space shows no abnormality. The lumbo-sacral space is narrow, and the edges of the vertebral bodies are sclerotic.

frame of normal physiological processes rather than as a pathological degeneration.

The difficulty is to decide when the condition is really of pathological significance. Our investigation has convinced us that definite degeneration must be presumed when ruptures are to be observed in the annulus.



*Fig. 4.*

Sections of the 5 lumbar discs of Case 56. Cf. radiograph in fig. 3. There is degeneration of the 1st, 3rd, 4th, and 5th discs. L5 disc is completely destroyed. The changes are most marked anteriorly in L1, and posteriorly in L3, 4 and 5.

The following observations have been made on discs showing radiographic evidence of degeneration. The type and localisation of the ruptures in the annulus are different at different levels of the lumbar spine. In the upper part they are more or less concentric, and in severe cases they may be found all round the annulus, equally anteriorly and posteriorly. In the two lower discs the degenerative changes occur mainly posteriorly, and often show a characteristic configuration.

Fig. 3 shows a lateral radiograph of a lumbar spine which has examples of different degrees of disc changes, slight changes in the first disc, very advanced degeneration in the fifth. Fig. 4 shows the cross sections of the discs. In the first disc there are definite changes all round, especially anteriorly and centrally. The third and fourth discs have, in spite of very slight radiographic changes, definite ruptures poster-



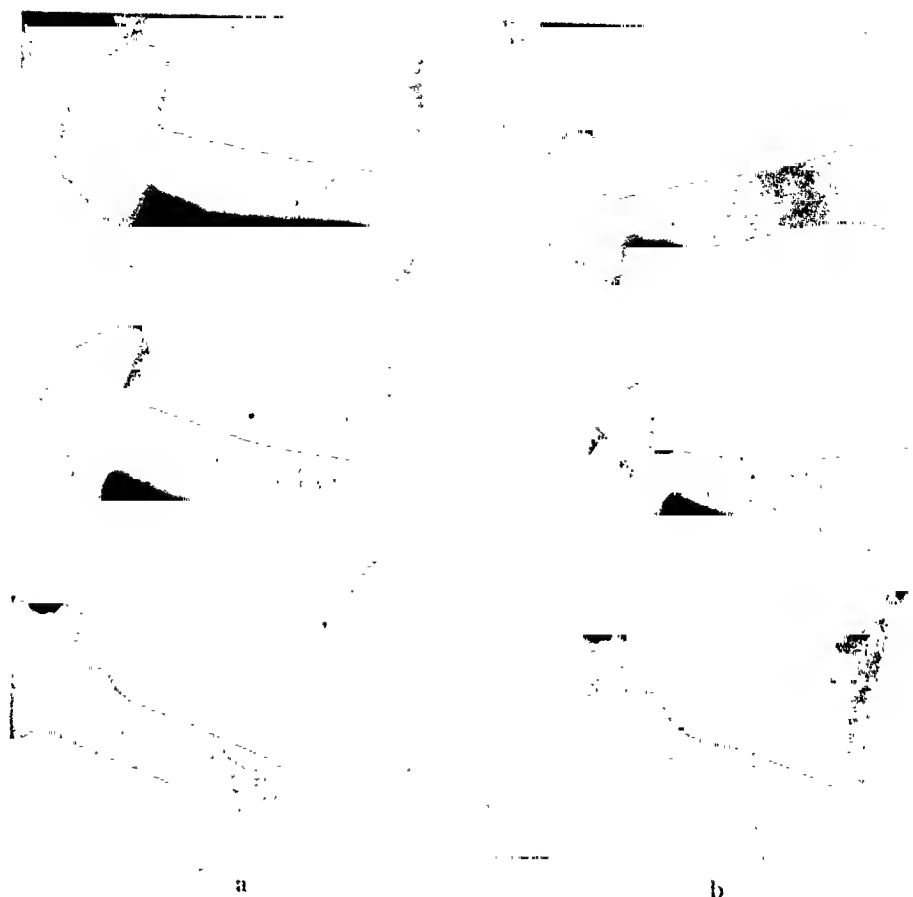


Fig. 5.

Radiograph of case 80. Post-mortem case.

a. spine in flexion. Normal height of disc spaces.

b. spine in extension without forcing. The L4 vertebra is displaced backwards. The intervertebral foramen is considerably reduced between L4 and L5, compared with the upper foramina.

iorly, though they are intact anteriorly. The fifth disc is completely destroyed.

When instability was present alone, without other radiographic sign of degeneration, the changes in the discs were the same as in those with narrowed interspace. The anatomical changes may be considerable, even though the radiograph shows only hyper-mobility.

Fig. 5 is a radiograph of a lumbar spine with instability of the fourth vertebra, and fig. 6 shows the fourth disc in

cross section: a sagittal, irregular, perforating rupture runs right through it posteriorly, and by a T-shaped division undermines a fairly large part of the annulus towards the intervertebral foramen. This is a common picture.



*Fig. 6.*

The unstable L4 disc from post-mortem case no. 80. Cf. radiograph in fig. 5. T-shaped ruptures in the posterior part of the disc running towards the intervertebral foramina on both sides and undermining the whole posterior border of the annulus fibrosus.



*Fig. 7.*

Intervertebral disc with partial ruptures within the postero-lateral borders of the annulus fibrosus. The nucleus pulposus flows out in the area of the rupture.

A total or subtotal interruption of the continuity of the fibrous structure of the annulus was noted in 16 out of the 17 cases with instability.

A common feature of degeneration of the two lower discs seems to be the presence of ruptures, radiating from the centre posteriorly and postero-laterally, and surrounded by smaller ruptures. The larger, main ruptures usually extend



*Fig. 8 a.*

Intervertebral disc with ruptures running through the posterior part of the annulus fibrosus in the midline.



*Fig. 8 b.*

Intervertebral disc with perforating ruptures through the postero-lateral part of the annulus fibrosus out towards the intervertebral foramen.

either sagittally or towards the intervertebral foramen. See figs. 7 and 8.

The sagittal ruptures very often divide, as in fig. 6, the lateral ruptures running more or less concentrically towards



*Fig. 9 a.*  
Degenerated intervertebral disc.



*Fig. 9 b.*  
Degenerated intervertebral disc.



*Fig. 9 c.*  
Disc with advanced degeneration.



*Fig. 10.*  
'Concealed' disc lesion.

the foramen. The whole posterior part of the disc may be affected in this way, although as a rule there is no prolapse.

In connection with the annulus ruptures, a special arrangement of the fibrous structure, apparently dependent on the localisation of the rupture, has sometimes been observed.



*Fig. 11.*

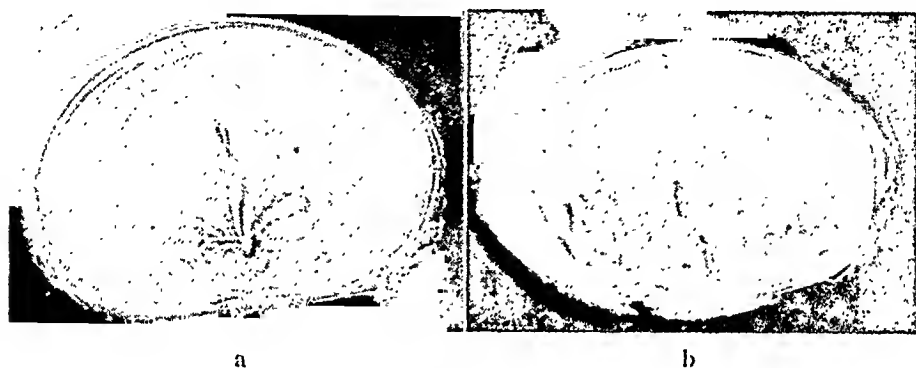
Case 59. Normal radiograph of the lumbar spine.

On the surface section the fibrous tissue appears to be "flowing out" towards the outer layers of the disc through the fissure. See figs. 7 and 8b. This may well be the case. With more pronounced ruptures in the annulus there is some retraction of its fibres, and tissue begins to be squeezed out through the ruptures because of the pressure within the disc.

In the fourth and fifth discs the anterior parts are generally intact, even with very advanced changes posteriorly. Fig 9a, b.

Among 500 discs, were found 11 prolapses, all backwards and all in the two lower interspaces. In all there were pro-

nounced ruptures of the annulus, and a more or less fibrous structure of the nucleus. Fig. 10 shows a L4 disc. Posterolaterally run two large ruptures, which mark a concealed prolapse in statu nascendi. This is a not uncommon picture. In all 11 prolapse cases there were, in addition to the transverse ruptures in the annulus, structural changes of the same kind as in the cases of disc degeneration described above.



*Fig. 12.*

a. The disc between L4 and L5 in Case 59. Cf. the radiograph in fig. 11. The disc shows early degenerative changes in the central posterior area, though no changes are seen on the radiograph.

b. The lumbo-sacral disc of Case 59. Cf. radiograph in fig. 11. Necroses and collapse in the whole posterior part of the disc. There are numerous ruptures in the annulus fibrosus. No changes are seen on the radiograph.

The prolapse is a part phenomenon in a general degeneration of the disc.

Above, we have been discussing the appearance of discs which radiographically showed narrowed interspace, sclerosis and osteophytes, or instability. However, ruptures in the annulus, and fibrosis and necrosis of the nucleus have been observed macroscopically in many cases over 30 years of age. Instability may seem to be an early roentgenological sign of disc degeneration, but it presupposes advanced changes in the structure of the disc, and when narrowed interspace, sclerosis, etc. occur, the changes are marked. On the other hand, it must be pointed out that negative radiographic findings are no proof that the disc is intact. A normal radio-

graph may conceal not inconsiderable degenerative changes (see figs. 11 and 12).

### CLINICAL OBSERVATIONS

The anatomical study just described impelled us to seek to establish on a clinical material how far disc degeneration could be observed roentgenologically. Therefore, to supplement the anatomical study we have investigated the cases examined and treated for "back trouble" at the Clinic during the years 1936-1946. Cases with tumours and T.B. have been excluded from the material, which comprises the diagnoses lumbago, lumbago-sciatica, disc degeneration, insufficientia dorsi, spondylosis deformans, spondylolysis, spondylolisthesis, sacralisations, hemi-vertebrae and other congenital abnormalities. During these 11 years 15,160 cases were seen, and 9419 patients were radiographed. Only the latter will be discussed. Some were not radiographed during the war because of shortage of films, and some simple cases of dorsal in-

Year of investigation	Number of cases examined	Number of cases examined		Number of cases with disc degeneration	Disc degeneration in % of number of cases radiographed
		Total	%		
1936 .....	491	350	71	53	15
37 .....	663	480	73	78	16
38 .....	800	506	64	123	24
39 .....	794	467	67	153	33
40 .....	1140	625	55	194	31
41 .....	1374	700	51	230	33
42 .....	1678	907	54	285	31
43 .....	1958	1117	53	452	41
44 .....	1869	1217	64	586	49
45 .....	2033	1361	67	680	50
46 .....	2360	1689	76	838	50
Total .....	15160	9419		3672	39

Fig. 13.

sufficiency were treated without radiography; some brought radiographs from other clinics, and afterwards it was not possible to form a definite opinion about them. Roentgenological signs of disc degeneration were found in 3,672 (39 %), see fig. 13.

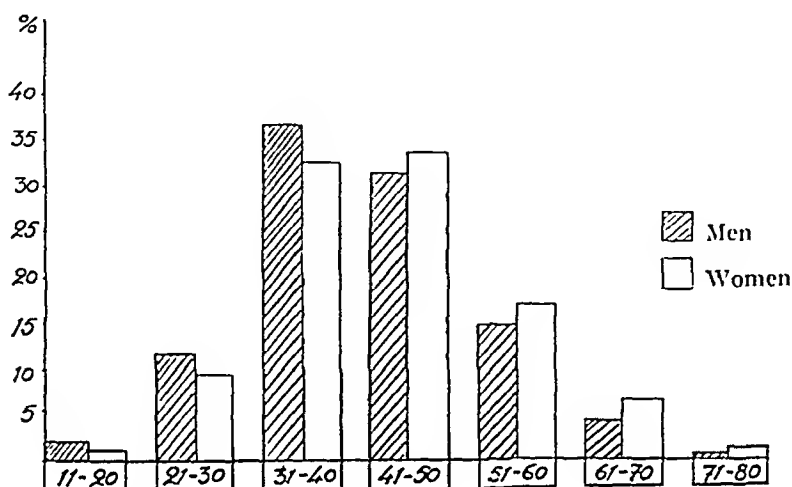


Fig. 14.

Age and sex distribution of the cases with disc degeneration.

In the table are included only cases where a diagnosis of disc degeneration was made the first time the patient was radiographed. A patient who, for instance, visited the Clinic in 1936, but was not examined radiographically until 1938, was registered in 1936. In this way the percentages for the first few years have come to be somewhat higher. During the earlier years of the table our attention was not so closely directed to disc degeneration, and this may to a certain extent explain the comparatively low proportion of diagnosed disc degenerations. During the years 1939-1942 the percentage of disc degenerations diagnosed on the bases of narrowed interspace, sclerosis and osteophytes, was comparatively constant. But since 1943 when our radiologist, Knutsson, began to use his instability tests, i.e. bending tests, the curve for diagnosed disc degeneration showed a definite rise. During the later years, roughly half of all the patients seen in the Clinic



because of low back pain have shown radiographic signs of disc degeneration.

Out of the 3,672 cases with disc degenerations, 2,081, or 57 %, were men, and 1,591, or 43 %, women. 1,530, or 74 % of the men were labourers. We have classed as labourers persons who, in the course of their work, have to lift and carry heavy objects. This classification is necessarily subjective, and its limits are mostly rather vague. The figures we have found scarcely support the belief that heavy manual labour plays an important part in the causation of lumbar disc degeneration. The percentages 74 % and 26 %—respectively—roughly represent the proportions of manual labourers and others in the community at large, and, in addition, the sex distribution does not show the preponderance of men which would be expected if heavy manual labour were of decisive importance.

Disc	%
Th 12-L 1	0.3
L 1-L 2	2.7
L 2-L 3	6.7
L 3-L 4	15.1
L 4-L 5	47.6
L 5-S-1	27.6

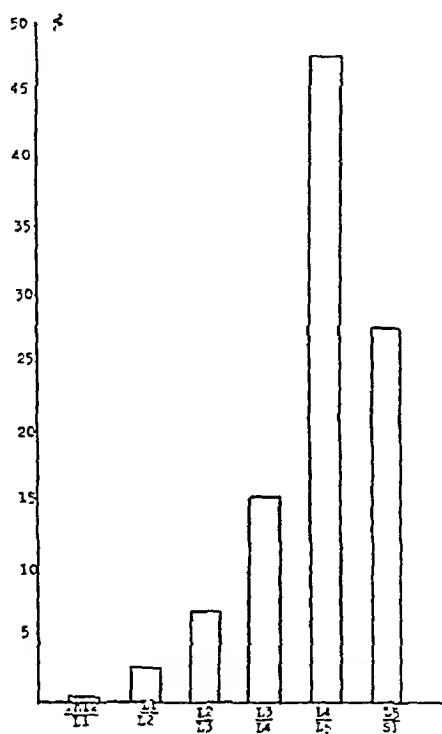
*Fig. 15.*

The site of the degeneration in 2104 cases with degeneration of an intervertebral disc. Radiographed 1944-6.

The majority of the patients with disc degenerations diagnosed radiographically were found in the age group 31-50 years, see fig. 14. The men show the highest frequency in the ages 31-40 years, the women in 41-50 years. It should be mentioned here that the great majority of cases coming to the Clinic have long-standing symptoms, usually resistant to therapy elsewhere.

The table does not show the age incidence of disc degeneration, but the age at which the patients have come to the Clinic, i.e. at the time when the symptoms were most pronounced. Patho-anatomically the degenerative changes in the discs are

progressive, and if there was full conformity between the degree of degenerative change and the symptoms, this would mean that the frequency would increase with the age. The curve seems to justify the assumption that the symptoms are to a certain extent transient, though healing, used in a patho-



*Fig. 16.*

The same shown diagrammatically. Cf. fig. 15.

anatomical sense, does not occur. In principle, the disc degeneration is an osteoarthritis, and it seems that in a similar manner the reactive changes in and around the disc may finally lead to a loss of its function with a consequent reduction of the symptoms.

The first part of this paper shows that instability is connected with disc changes, which conform in principle with those which are to be observed in radiographic disc degeneration. After the publication of Knutsson's observations in 1944,

cases with instability without other radiographic abnormality, or with only slight signs of disc degeneration were studied. During the years 1944-1946, instability without other signs of disc degeneration was observed in 303 (15 %) out of 2,104 cases of disc degeneration. The distribution of the different degenerated discs in these 2,104 cases is shown in fig. 15.

Almost half, or 47.6 % of the degenerations were localised to the fourth disc, and in 75.2 % to the fourth and fifth discs. It should be noted that 27.6 % for the fifth disc is probably a minimum figure in view of the difficulty of detecting changes in this often physiologically thinner disc.

Site	%
Th 12-L 1	0
L 1-L 2	0,7
L 2-L 3	4,2
L 3-L 4	18,5
L 4-L 5	70,3
L 5-S 1	6,3

*Fig. 17.*

The site of the instability in 303 cases with no other sign of disc degeneration.

Site	%
Th 12-L 1	0
L 1-L 2	1,8
L 2-L 3	8,0
L 3-L 4	20,3
L 4-L 5	60,1
L 5-S 1	9,8

*Fig. 18.*

The site of the instability in 275 cases with other signs of disc degeneration.

Scrutiny of the 303 discs with instability alone shows, that in 70.3 % the changes were localised to the fourth disc (see fig. 17). This is in conformity with the anatomical findings, where in 12 out of 17 intervertebral discs with instability, i.e. 70.6 %, the changes were in the fourth disc.

Instability was combined with other radiographic signs of degeneration in 275 cases (see fig. 18). In this group instability of the fourth disc was observed in 60.1 % of the cases.

### SUMMARY

100 lumbar spines taken out from post mortem specimens have been studied. They were radiographed in various positions of flexion and extension, and the stability of the spines, i.e. of the discs, was assessed. Other radiographic changes were also recorded. The intervertebral discs were sectioned horizontally, and the changes observed in the nucleus pulposus and annulus fibrosus were recorded. Particular attention was paid to ruptures in the annulus fibrosus.

The records of 15,160 patients seen in the Clinic for lumbar pain, excluding those with tuberculosis and tumours, during the period 1936-1946, have been collected; and the incidence of radiographic signs of disc degeneration in the lumbar spine has been studied.

The post mortem material showed:

- 1) Disc degeneration acquires patho-anatomical importance when the annulus fibrosus begins to rupture.
- 2) In the lower lumbar discs the ruptures in the annulus were mostly localised to the posterior part of the disc. From the centre they were directed either sagittally or laterally backwards to the intervertebral foramen. In the upper discs the ruptures were frequently also anterior.
- 3) Marked degeneration may be present without any radiographic changes. Thus a normal radiograph does not exclude an important degeneration in a disc.
- 4) In 16 out of 17 cases with instability there were severe changes in the disc and ruptures in the posterior part of the annulus fibrosus.
- 5) When the radiograph showed reduced disc space, sclerosis or osteophytes, the corresponding disc was severely damaged.

- 6) In cases with prolapse of the disc the structure had the same patho-anatomical characteristics as in cases of simple degeneration. Disc prolapse is a part phenomenon of degeneration of the disc.

The clinical material showed:

- 1) Radiographic disc degeneration was found in 39 % of all the patients that came to the Clinic for "back trouble", and in 50 % of the material covering the last 2 years of the investigation.
- 2) 43 % of the cases with disc degeneration were women, and 57 % men.
- 3) 74 % of the men were engaged in physical work of some kind or other. This proportion agrees roughly with the country's proportion of labourers.
- 4) The authors found no evidence that heavy physical work is the direct cause of the disc changes.
- 5) Disc degeneration occurs most frequently (in 47.6 %) in the 4th lumbar disc, and in 75.2 % in the 4th and 5th discs together.
- 6) In 15 % instability was the only radiographic change. In 70.3 % [of these] it occurred at the 4th disc.
- 7) The investigation shows that radiography does not give satisfactory information on the condition of the disc in cases of lumbar pain. The instability test is a valuable contribution to diagnosis.

#### RESUME

Les auteurs ont examiné 100 colonnes lombaires provenant d'autopsies. Après la dissection, ces colonnes ont été radiographiées dans différentes flexions ventrales et dorsales afin de pouvoir apprécier la stabilité des vertèbres. Des modifications radiologiques ordinaires ont été enregistrées. Des disques étaient transpercés horizontalement et il y avait des altérations dans le nucleus pulposus et l'annulus fibrosus. Les ruptures de l'annulus fibrosus notamment ont été étudiées.

Les auteurs ont rapproché d'autre part tous les cas cliniques soignés à l'hôpital pour des douleurs lombaires entre 1936 et 1946, soit en tout 15,160 cas, en éliminant tous ceux atteints de tuberculose ou de tumeurs. Ils ont étudié la fréquence radiographique des dégénération des disques dans la colonne lombaire.

*En ce qui concerne le matériel provenant des autopsies, cet examen a fait ressortir ce qui suit:*

1. Quand il y a rupture de l'annulus fibrosus, il semble qu'il y ait une dégénération certaine du disque.
2. Les ruptures de l'annulus observées dans les disques lombaires inférieurs ont été localisées dans la partie dorsale des disques, allant soit du centre en arrière, soit en arrière latéralement, en direction du trou intervertébral. Dans les disques lombaires supérieurs, les ruptures sont plus fréquemment ventrales.
3. Il pouvait y avoir des modifications dégénératives prononcées sans qu'elles apparaissent sur la radiographie. Une radiographie normale n'exclut donc pas la présence de modifications dans les disques.
4. Lorsqu'il y avait instabilité, on a trouvé dans 16 cas sur 17 des modifications sensibles et l'on a trouvé des ruptures dans la partie postérieure de l'annulus fibrosus.
5. Lorsque la radiographie a décelé une diminution dans l'épaisseur du disque, des scléroses ou des ostéophytes, les disques cartilagineux correspondants montraient des modifications extrêmement nécrotiques.
6. Dans les cas où il y avait prolapsus du disque, les modifications anatomo-pathologiques présentaient le même caractère que les cas de simple dégénération du disque. Le prolapsus du disque fait partie du phénomène de la dégénération du disque.

*Dans le matériel clinique, les observations suivantes ont été faites:*

1. Sur l'ensemble de ce matériel, on a constaté des dégénéra-

- tions radiographiques de disque dans 39 %, pour les deux dernières années dans 50 % des cas.
2. Sur tous les cas de dégénération du disque, il y avait 43 % de femmes et 57 % d'hommes.
  3. Parmi les hommes, 74 % étaient des travailleurs. Ceci correspond à peu près au pourcentage des travailleurs dans la population masculine.
  4. Les auteurs n'ont pas trouvé la preuve qu'un dur travail corporel est la cause directe de la fréquence des modifications dégénératives des disques.
  5. La fréquence de la dégénération des disques dans les différents intervalles lombaires établit que le plus grand nombre est localisé dans le disque de la 4ème vertèbre lombaire, à savoir 47,6 %. Dans 75,2 % des cas, les modifications du disque se trouvaient dans les deux disques lombaires inférieurs.
  6. On a constaté de l'instabilité dans 15 %, sans autres modifications radiologiques. Dans 70,3 % des cas, celle-ci était localisée au 4ème disque.
  7. Cette enquête semble prouver que l'examen radiographique ne donne pas à lui seul des renseignements satisfaisants sur l'état des disques dans les cas de douleurs lombaires. L'épreuve de l'instabilité constitue un précieux apport diagnostique.

#### ZUSAMMENFASSUNG

100 Lendenwirbelsäulen die der Leiche entnommen wurden, sind untersucht worden. Sie wurden in verschiedenen Flexions- und Extensionsstellungen Röntgenuntersucht und die Stabilität der Wirbel wurde festgestellt. Ondre röntgenologische Veränderungen wurden ebenfalls notiert. Die Zwischenwirbelscheiben wurden durch horizontale Schnitte zerlegt und die im nucleus pulposus und annulus fibrosus wahrgenommenen Veränderungen wurden aufgezeichnet. Besondere Aufmerksamkeit wurde den Rupturen im annulus fibrosus gewidmet. Ausserdem wurden insgesamt 15,160 Fälle ge-

sammelt, die im Krankenhaus wegen Schmerzen in der Lumbalregion während der Jahre 1936—1946 untersucht wurden. Ausgenommen waren Fälle mit Tuberkulose oder Tumoren. Das Vorkommen von röntgenologischen Zeichen von Diskusdegeneration in der Lendenwirbelsäule wurde studiert.

Das von der Leiche gewonnene Material zeigte:

- 1) Eine sichere Scheibendegeneration ist vorhanden, wenn der annulus fibrosus geborsten ist.
- 2) In den kaudalen Lendenzwischenwirbelscheiden waren die Rupturen im annulus in den rückwärtigen Partien der Scheibe gelegen und entweder zentral nach hinten oder lateral nach hinten gegen das foramen intervertebrale gerichtet. In den oberen Scheiben waren die Rupturen auch oft im vorderen Anteil zu sehen.
- 3) Ausgeprägte degenerative Veränderungen mögen vorhanden sein ohne dass es zu röntgenologischen Veränderungen kommt. Daher schliesst ein normales Röntgenbild Veränderungen in der Scheibe nicht aus.
- 4) In 16 von 17 Fällen mit Zeichen für Instabilität fand man schwere Veränderungen der Scheibe und Rupturen im rückwärtigen Teil des annulus fibrosus.
- 5) Wenn das Röntgenbild einen verminderten Wirbelzwischenraum, Sklerose oder Osteophytenbildung zeigte, waren die entsprechenden Knorpelplatten ausgesprochen nekrotisch verändert.
- 6) Fälle mit Scheibenprolaps zeigten dieselben Charakteristika wie Fälle mit einfacher Degeneration. Der Scheibenprolaps ist Teilerscheinung einer Scheibendegeneration.

Das klinische Material zeigte:

- 1) Röntgenologisch wurde Scheibendegeneration in 39 % des gesamten Materiales und in 50 % des Materiales der letzten zwei Jahre gefunden.
- 2) 43 % der Fälle mit Scheibendegeneration waren Frauen und 47 % waren Männer.



- 3) 74 % der Männer hatten körperliche Arbeit zu verrichten. Diese Anzahl stimmt ungefähr überein mit der Anzahl der Arbeiter des Landes.
- 4) Die Verfasser fanden keinen Beweis dass schwere körperliche Arbeit die direkte Ursache der Scheibenveränderungen ist.
- 5) Das Vorkommen von Scheibendegeneration in verschiedenen lumbalen Zwischenwirbelräumen zeigt dass sie ofttest, d. i. in 47,6 % in der 4. Lumbalscheibe und in 75,2 % in der 4. und 5. Scheibe auftritt.
- 6) Mangelhafte Stabilität war die einzige röntgenologische Veränderung in 15 % der Fälle. In 70,3 % trat diese in der 4. Scheibe auf.
- 7) Die Untersuchung zeigt dass man keine zufriedenstellende Auskunft über den Zustand der Scheibe durch Röntgenuntersuchung in Fällen von Schmerzen in der Lumbalregion erhalten kann. Die Instabilitätsprobe ist ein wertvoller Beitrag zur Stellung der Diagnose.

#### LITERATURE

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## UEBER DIE HABITUELLE LUXATIO STERNO- CLAVICULARIS

VON

STEN VON STAPELMOHR

In Acta Orthopaedica Scandinavica 1932, III, 1 habe ich eine Zusammenstellung von in der Literatur publizierten 32 Fällen von Luxatio sternoclavicularis nebst 4 von *Nilsson* und mir selbst beobachteten Fällen gemacht. Sie wurden damals von mir in kongenitale (A. 2 Fälle) und erworbene (B. 34 Fälle) Luxationen und Subluxationen eingeteilt. Diese Gruppe konnte wieder in doppelseitige symmetrische (B: a: 1 u. 2) und einseitige (B: b 3 u. 4) eingeteilt werden. In den beiden Gruppen waren Fälle von traumatischen und spontanen Genese. Wenn ich von den einseitigen, ganz traumatischen Luxationen absehe, die die grösste Gruppe bilden und auf welche damals nicht näher eingegangen wurde, stellte ich 6 traumatische doppelseitige und 10 spontane doppelseitige (wovon 2 bis dahin nicht veröffentlichte Fälle 17 u. 18) zusammen. Ferner erwähnte ich 15 spontane oder nach einem sehr geringen oder chronischen Trauma aufgetretene Luxationen und fügte 2 neue Fälle zu (35 u. 36).

Das Alter bei den erworbenen Fällen für das erste Auftreten war zwischen 8 und 20 Jahren. 19 waren Weiber und 8 Männer.

Seitdem sind ab und zu neue Fällen publiziert worden. Da ich ferner 2 Fälle observiert habe und ein Fall mir aus Ludvika Krankenhaus (Dr. H. *Wahren*) mitgeteilt ist, will ich hier meine Erfahrung aus 1932 ergänzen und diese beobachteten Fälle und das Operationsresultat nach einem längeren

Zeitraum mitteilen. 1932 war die Beobachtungszeit längst 3 Jahre.

*Fall 17. (Verfasser. Siehe bezügl. Publikation S. 9 u. 32):* Bei der Untersuchung 13/8 1948, also mehr als 20 Jahre nach der Operation, kann konstatiert werden, dass die sternalen Klavikularenden auf normale Weise in seinen Gelenkpfannen verweilen. Volle Beweglichkeit in den Schultergelenken. Keine Prominenz der Klavikularenden. Die Patientin sagt, dass die kein Ungemach ihres alten Leidens hätte. Sie bemerkt nur eine leichte Müdigkeit, wenn sie ein Rückenrönsel trüge. *Röntgen (Morales):* Auf der vorderen Seite beider Sternoklavikulargelenke und auf dem Sternum ziemlich kräftige Osteophyten. Die Gelenke haben im übrigen keine wesentlichen Veränderungen. Kein Zeichen einer Subluxationsstellung.

Die Operationsmethode zeigt also 20 Jahre nach der Operation ein anatomisch und funktionell ausgezeichnetes Resultat. Die 2 neuen Fällen sind:

*Fall 37 (Wahren):* 16-jähriges Mädchen. Seit 5½ Jahre hat man bemerkt, dass das linke Schlüsselbein luxiert wird, wenn der Arm auswärts-aufwärts gehoben wird. 3 Jahre früher hat die Patientin Massage bekommen ohne Effekt. Bei der Abduktion des Armes tritt eine Verrenkung am sternalen Ende des linken Schlüsselbeines nach vorn hervor. Gleichzeitig Schmerzgefühl. 1/7 1940 Operation (*Wahren*) nach der Methode des Verfassers. Der eingelegte Metallnagel wurde schon nach einer Woche extrahiert, weil derselbe nach aussen gedrängt war und unter der Haut palpiert werden konnte. Der Oberarm wurde 3 Wochen an den Thorax fixiert. Bei der Untersuchung 3 Jahre nach der Operation nichts besonderes. 2 Jahre nachher konnte ein beginnendes Rezidiv konstatiert werden.

*Fall 38 (Verfasser):* 24-jährige Zuschneiderin der Textilindustrie (*Journ.* 2387/46). Seit einem Jahre hat sie ohne direkt bekannte Ursache ein Knacken im rechten Sternoklavikulargelenk beim Heben des Armes nach aussen oder vorwärts bemerkt. Niemals Schmerzen im Sternal- oder Klavikulargegenden gehabt. Bei der Armhebung vorwärts oder aufwärts luxiert sich das mediale Schlüsselbeinende vorwärts und aufwärts. *Röntgen* zeigt normale Verhältnisse der rechten Seite ohne Klavikularveränderungen. 14/11 1946 Operation nach vom Verf. angegebener Methode. Fixation des Armes eine Woche. 2 Monate später wurde der Metallnagel entfernt. Nachher gesund auf dieser Seite.

Im Okt. 1947 fangen dieselben Symptome im linken Sternoklavikulargelenken an, wo eine Subluxation nach vorne und aufwärts konstatiert

wurde. *Röntgen* zeigt beiderseits keine Veränderungen der Sternoklavikulargelenke. Der mediale Teil der linken Klavikel zeigte im Vergleich der rechten eine leichte Abschwächung gegen das Sternum mit einem kleinen Apophysenkern. An der rechten Seite normale Verhältnisse. 5/2 1948 dieselbe Operation der linken Seite. Eine breite Narbe von der vorigen Operation wurde excidiert, so dass der ganze Operationsschnitt einen nach unten konvexen Bogen, ähnlich einem niedrig liegenden Kragenschnitt nach *Kocher* bildet. Fixation des linken Armes 1 Woche. 2 Monate später wurde der Metallnagel entfernt. Bei der Untersuchung 1949 8/10 normale Bewegungen in der Schulter- und Klavikulargelenken.

Von Interesse ist festzustellen, dass mein Fall 38, der anfangs einseitig war, später in die doppelseitige spontane Gruppe eingeordnet werden muss (B: a: 2). Meine Vermutung 1932, dass man die spontanen doppelseitigen und die spontanen einseitigen Fälle in eine Gruppe vereinigen könnte, „bei der die Disposition für die Entstehung des Leidens das zusammenbindende Moment wäre, ... sehr wohl möglich ist“, scheint richtig zu sein. Der Zeitabstand zwischen den initialen Symptomen der beiden Seiten war 2 Jahre. Keine Ursache weder zu der ersten noch zu der zweiten Luxation kann herausgefunden werden. Das Alter der Patientin beim Beginn des Leidens war 22 Jahre, also ein wenig älter als die früher von mir beobachteten Fälle. Im Falle 37 erscheint die Krankheit im Alter von 10 Jahren.

Hinsichts des Operationsfolges muss hier erwähnt werden, dass in meinem Fall 17 kein Rezidiv und eine ausgezeichnete Funktion 20 Jahre nach der Operation gemäss meiner Methode konstatiert werden kann. In meinem Fall 38 auch kein Rezidiv 2¾ Jahre nach der Operation. Im Fall 37 wurde nach einer 5-jährigen Rezidivfreiheit beginnender Rückfall bemerkt. Hier wurde der Nagel schon nach einer Woche entfernt, was möglicherweise Einfluss auf die Entstehung des Rezidivs haben kann. Man muss deshalb erwägen, ob nicht irgend eine andere Art der Fixation als mit Metallnagel ratsam wäre? Beispielsweise mit einem durch die Haut gehenden, über einem Bleiknopf geknüpften, wegnehmbaren, rostfreien Metalldraht.

## ZUSAMMENFASSUNG

Im Jahre 1932 beschrieb der Verfasser in dieser Zeitschrift (1932, III: 1) eine neue Operationsmethode für die Luxation des Sternoklavikulargelenkes. Er veröffentlicht nun zwei weitere Fälle, die nach dieser Methode behandelt wurden. Ein Fall, operiert in 1946, hatte kein Rezidiv im Verlaufe von  $2\frac{3}{4}$  Jahren, der andere, operiert in 1940, zeigte ein Rezidiv 5 Jahre nach der Operation, möglicherweise weil die Niete 1 Woche nach der Operation entfernt worden war. Ein Fall von den im Jahre 1932 veröffentlichten Fällen wurde 20 Jahre nach der Operation nachuntersucht ohne dass ein Rezidiv gefunden werden konnte.

## RESUME

L'auteur, qui avait décrit une nouvelle méthode d'opération de la luxation sterno-claviculaire dans cette Revue (1932 : III : 1) rapporte maintenant 2 nouveaux cas traités par cette méthode. L'un opéré en 1946 n'a pas eu de rechute pendant 2 ans  $\frac{3}{4}$  ; l'autre, qui avait été opéré 5 ans auparavant, a eu une rechute au bout de cinq ans, peut-être parce que le rivet métallique avait été enlevé une semaine seulement après l'opération. Un des cas de 1932, réexaminé, a montré qu'il n'y avait eu aucune rechute durant les 20 années qui ont suivi l'opération.

## SUMMARY

In 1932 the author described in this journal (1932, III: 1) a new method of operation for luxation of the sterno-clavicular joint. He now reports 2 further cases treated by this method. One, operated in 1946, has had no recurrence for  $2\frac{3}{4}$  years. the other, operated in 1940, was found to have recurred 5 years later, perhaps because the rivet was removed 1 week after operation. One case from the 1932 paper has been re-examined 20 years after operation; there has been no recurrence.

## TUBERCULOSIS OF THE GREATER TROCHANTER

BY

IVAR ALVIK

Although tuberculosis of the greater trochanter is not one of the most common forms of metastatic tuberculosis, it is not rare. Yet it has not been much discussed in the literature. *Sven Johansson* found it in 2.33 % of his cases of bone and joint tuberculosis. *Clairmont*, *Winterstein* and *Dimtza* write that it is rare; they found only 3 cases. *Melton* found 21 cases; *Meyerding* and *Mroz* 19; *Sassen* 6; *Kremer* and *Wiese* 2; *Stracker* and *Ingianni* each 1.

TABLE 1

*Sex and Age Distribution at Onset of Symptoms in 36 Patients with Tuberculosis of the Greater Trochanter.*

Age	Male	Female	Total
0-10 years .....	2		2
10-20 „ .....	3	8	11
20-30 „ .....	5	7	12
30-40 „ .....	6		6
40-50 „ .....	3	2	5
Total .....	19	17	36

During the 12 years Martina Hansen's Hospital has been open, 36 cases of tuberculosis of the greater trochanter have been treated, i.e. barely 2 % of all the cases of bone and joint tuberculosis. Table 1 shows their distribution, according to

sex and age. The sexes are nearly equally represented; and, as in other manifestations of tuberculosis most cases were between 20 and 30 years of age. The right side was affected in 21 cases, the left in 15.

#### MODE OF SPREAD OF THE DISEASE

In most cases of bone and joint tuberculosis the infection is brought by the blood stream. The comparatively rich blood supply of spongy bone in the greater trochanter and adjoining part of the femur should, as in other bones, favour this mode of spread of the disease. Other routes of the infection in this region must be mentioned because of the favourable conditions. In almost every case of tuberculosis of the greater trochanter we find infection of its bursa, which lies like a small cape round its lateral portion. Not infrequently the disease is confined to this bursa, while the greater trochanter itself shows no demonstrable changes. It is, therefore, probable that the bursa is the primary, and the greater trochanter the secondary focus. The bursa may be infected by the blood stream as in tuberculosis hygromata of the hand and wrist; it may also be infected by gravitation abscesses from tuberculous foci at a higher level, e.g. from the vertebrae passing out of the pelvis in front of the anterior superior spine of the ilium, or through the trigonum lumbale along the muscles going to or close by the greater trochanter, i.e. in the tensor fasciae latae and the gluteal muscles, and from an ilio-sacral infection. Medial psoas abscesses on the other hand, do not usually track toward the greater trochanter, but rather come in close contact with the lesser trochanter, in which, as far as I know, there is no record of isolated tuberculosis.

*Waldenström* believes that tuberculosis of the bursa of the greater trochanter often begins as tuberculosis of the greater trochanter; *Fliegel*, that a psoas abscess can infect both the hip-joint and the greater trochanter, and *Kremer* and *Wiese* that the infection may be secondary.

Table 2 gives the sites of other tuberculous foci in the 36

TABLE 2

*Other Tuberculous Foci in 36 Patients with Tuberculosis of the Greater Trochanter*

Site of lesion	Before the onset of symptoms from the trochanter	After the onset of symptoms from the trochanter	Total
Spine .....	7	1	8
Sacro-iliac joint .....	3		3
Hip joint .....		3	3
Shoulder joint .....	3		3
Knee .....	1		3
Ankle .....	1		1
Pelvic abscess .....	1		1
Lungs and pleurae .....	10	2	12
Other T.B. lesions outside bones and joints .....	6	2	8
Total .....	32	8	40

cases of trochanteric tuberculosis, and the chronological relationship of these foci to the trochanteric disease. Spondylitis and trochanteric tuberculosis were present together in 8 cases, and in 7 of them a gravitation abscess was found on the same side as the trochanteric tuberculosis, which had begun a considerable time after the gravitation abscess. In 23 of the 36 cases there were other extrapulmonary tuberculous foci. In the remaining 13 cases, the disease of the greater trochanter was the only extrapulmonary lesion.

One would except to find that tuberculosis of the greater trochanter occurs when there is tuberculosis of the hip with peri-articular abscesses, but there is no such case in my material. In 3, however, tuberculosis of the hip developed secondarily to the tuberculosis of the greater trochanter: in all 3 cases the interval between the appearance of the two foci was so long that it is probable that the disease had spread directly from the greater trochanter to the hip. *Sassen* has also reported one case in which the hip-joint was infected



from the greater trochanter: his patient had multiple, periosteal, tuberculous pelvic abscesses, and later developed tuberculosis of the greater trochanter.

*It may therefore be assumed that in 11 of the 36 patients examined there was direct spread of the disease to the region of the greater trochanter from other tuberculous lesions. In the remaining 25 cases the disease in the region of the greater trochanter was probably primary.*

For both categories there remains the question whether the disease began in the bursa or in the bone. Neither clinical nor radiographic examination of my material gives a definite answer to this question, but certain observations deserve mention.

In 1 case, the focus in the trochanter was discovered during routine radiography of the skeletal system in a case with tuberculosis of the knee-joint: there was no demonstrable involvement of the bursa. In 2 other cases the destructive process had advanced so far in the greater trochanter before the bursitis gave rise to symptoms that it is natural to assume that the disease had begun in the bone.

In the remaining 33 cases there was no reason to believe that the disease had begun in the bone, and certain findings suggested that it had begun in the bursa. In 2, no sign of bone destruction could be found on the radiographs or at operation. In most of the cases the first radiographic sign of bone involvement was a periosteal ossification with blurring of the outline of the lateral surface of the greater trochanter in the position of the bursa. Usually, this periosteal reaction was present for a considerable time before there was any sign of destruction of the bone itself. In several cases slight surface erosion of the bone, just under the bursa, was observed at operation. The ilio-tibial tract and the fascia lata exert considerable pressure on the bursa, and therefore also on the subjacent bone. This fact is, in my opinion, very important, and will be dealt with below under the heading of treatment.

*The early appearance of the bursitis in relation to the disease of the bone, the massive periosteal reaction, and the*

*fact that the bone destruction often begins as a superficial erosion on its cortex, all suggest that in many, possibly most, cases the disease begins in the bursa.* As there was no demonstrable difference between the cases in which the disease started from a gravitation abscess from a focus at a higher level and those in which it began in the trochanteric region, we may assume that in this group also the disease usually begins in the bursa.

7 of the 36 patients said that the disease of the greater trochanter began either immediately or some time after considerable trauma to the trochanteric region. These statements can hardly by themselves prove that trauma helped provoke the disease, though such a possibility cannot be excluded.

### SYMPTOMATOLOGY

Pain and tenderness in the trochanteric region are the most constant symptoms. They were noted in 35 of the 36 cases; the pain was worse on walking, and usually on passive adduction of the limb. A swelling corresponding to the trochanteric bursa is an early sign; atrophy of the muscles of the corresponding thigh and buttock appears much later, and, even when the disease is advanced, there is not the marked muscular atrophy, which develops comparatively early in tuberculous arthritis. Muscle insufficiency and diminished thigh-pelvis stability can be found comparatively early, but rather because of increased pain when the stability is tested than because of muscle atrophy. The same is true of the patient's halting gait.

Sinus formation is the most common complication; it was present in 22 of the 36 cases. Some of the sinuses were already present, but many only developed after operation.

### TREATMENT

Tuberculosis of the greater trochanter is not so crippling as tuberculous arthritis. Yet it is to some extent difficult to

treat and it distresses the patient on account of its chronic course and frequent relapses.

Surgery is combined with ordinary general treatment of the tuberculous infection. 66 operations were performed on 31 out of the 36 cases, either before (29), or during (37) hospitalisation. In 24 the greater trochanter was resected, while in 13 the focus was excised without a radical resection of the bone. Simple incisions are not included in the figures. 2 patients each had 5 operations.

Surgery aims at the radical removal of all diseased tissue, and at resection of the greater trochanter, whenever it is affected, even if there is only a periosteal reaction or infiltration of the overlying muscle and fascial attachments is visible at operation. When the disease begins in the bursa and only secondarily attacks the greater trochanter, one would expect early periosteal changes to heal, when the source of infection has been eliminated. This hope is often disappointed, probably because of the considerable constant compression by the tractus ilio-tibialis and fascia lata, which are particularly tight when they have shrunk as the result of inflammation and scar formation.

#### OPERATION TECHNIQUE AND USUAL FINDINGS AT OPERATION

The technique of the radical operation (removal of all diseased tissue and resection of the greater trochanter) might be expected to be fairly simple; the region is easily accessible, and there is little to fear from the neighbouring structures, but there are some important anatomical and functional considerations.

The skin incision should be made over the posterior border of the greater trochanter from a point a little below the crest of the ilium to at least 10-12 cm. below the greater trochanter. Sinuses in the line of the incision are excised; those situated more anteriorly should be excised separately. Infiltrations in the subcutis are radically removed, and the fascia is exposed.

Whenever the bursa is found perforated, whether with or without a skin sinus, there is always some infiltration of the fascia lata and tractus ilio-tibialis, both of which, on account of cicatricial contraction, may be so taut that after longitudinal division it is almost impossible to raise their margins from the underlying structures. *Therefore, all the infiltrated or sclerotic and retracted portion of the fascia and ilio-tibial tract should be radically removed, even when there seems to be no active inflammation.*

If the fascia and ilio-tibial tract show no sign of pathological changes, they should be incised longitudinally at the posterior part of the trochanteric region. The divided fascia can now be easily retracted to both sides, and the underlying tissues are easily accessible. If the fascia is divided over the centre of the greater trochanter or anterior to it, it is difficult to pull its posterior portion far enough aside to give access to the region under the gluteus maximus without a transverse division.

In most cases the trochanteric bursa is found to be already perforated by large diverticula, sometimes raw, sometimes more fibrous and thick-walled, full of brawny connective tissue, granulation tissue, or pus, according to the activity and age of the lesion. Occasionally, these diverticula extend some way down the thigh, not infrequently anteriorly under the tensor fasc. lat. muscle. But they are largest and most constant posteriorly and proximally, deep to the gluteus maximus muscle, whose flattened attachment to the inner side of the fascia lata is usually completely destroyed. These posterior diverticula may extend right up to the incisura ischiadica.

In 2 cases a connexion between a gravitation abscess and the lesion in the greater trochanter could be traced at operation. In one, who had previously been treated for ilio-sacral tuberculosis, a sinus ran from the focus in the greater trochanter towards the lower part of the iliosacral joint. Only its lower part was patent; it resembled an ordinary diverticulum of the bursa; but further up its lumen diminished, and its

upper portion was a solid band, without any lumen. In this respect it was unlike an ordinary bursal diverticulum, of which the distal end often presents a bulbous expansion. In the other case, with a history of a spondylitic gravitation abscess, there was a similar sinus in front of the greater trochanter; extending in the direction of the region between the spinae ilii ant. sup. and inf.; it, also, dwindled above, and became a scarred band without a lumen.

Rarely, a sinus communicates directly with bone. In most cases there is sclerotic thickening, with some ossification of the periosteum of the greater trochanter under the bursa. *Stracker* examined one case microscopically, and found that the tendon attachments had been partly converted into cartilage, with ossification. Under the periosteal thickening there may be a superficial erosion of the bone, and ill-defined cavities filled with masses of granulation tissue and sequestra. It is not always easy to demonstrate either the superficial erosions, or the foci of destruction in the spongy bone radiographically before operation. The greatest value of radiography is in showing the relationship of the tip of the greater trochanter to any destructive process which may exist. *For, when the greater trochanter is resected any diseased periosteum should also be removed, and the rest of the greater trochanter isolated subperiosteally.* The periosteum of the tip of the greater trochanter however must never be removed, even when it is diseased. If the tip itself is not diseased, it can be chiselled off without disturbing the muscle attachments, and later replaced. If it is diseased, it is isolated subperiosteally, and the periosteum, if it is also suspect, is scraped as clean as possible. The gluteus medius is the most important stabilizing factor between pelvis and thigh, and its attachment must therefore not be separated from the periosteum, as without the periosteum it is very difficult to get a functionally satisfactory connexion between the muscle and femur. If the periosteum has been preserved, the new attachment heals readily. Pelvic instability, which, is so common after operations

on the greater trochanter, is primarily due to insufficiency of the gluteus medius.

The next step is to chisel off most of the greater trochanter, and round off the resection surface. The periosteum with its muscle attachments is as far as possible preserved, and the remains of the broad attachment of the gluteus maximus are secured to the border of the anterior portion of the fascia. If this is not feasible, it is secured to the periosteum on the anterior surface of the resected greater trochanter. If any, however little, of the fascia lata and tractus ilio-tibialis has been excised, they must not be sutured. It is best not to close even a longitudinal incision, for fear of secondary scarring with retraction and consequent tension in, and pressure on, the underlying tissues. On the other hand, the anterior border of the fascia can be secured to the under surface of the posterior subcutis, after it has been dissected free, to facilitate closure of the wound in layers.

After the operation the limb is immobilised in good abduction to facilitate the healing of the soft tissues which have been loosened over the tip of the greater trochanter. With the same object, the patient should remain in bed for at least three to four weeks after the operation unless the tip of the greater trochanter has been left intact.

In order to facilitate the detection of small sinuses and diverticula in the subcutaneous tissues, a dye may be injected into a sinus before the operation. It rarely goes into the large and deeply situated diverticula, but these are comparatively easy to find and remove, provided one has a good view of the field of operation.

A haematoma in the wound is one of the most common postoperative complications. It could, of course, be avoided by the insertion of a drain, preferably some distance from the incision in the skin. But drainage is seldom advisable in cases of tuberculosis because of the risk of sinus formation. There is the same risk if a haematoma is evacuated through the operation wound, and the most effective method is to aspirate

a day or two after the operation through a needle thrust deep into the wound. Aspiration is repeated as long as fluid can be obtained. This procedure should be followed even when there is no clinical evidence of haematoma; in most cases, blood, or at any rate blood-stained fluid, can be aspirated.

### THE FOLLOW-UP EXAMINATION

One patient could not be traced. The other 35 were re-examined, either by myself in person or by letter. The average observation period between operation and re-examination varied from 6 months to 10 years, with an average of 3.9 years. The average interval between the first symptoms and the re-examination was 11.7 years.

TABLE 3  
*Physical Fitness after Tuberculosis of the Trochanter.*

	Total resection alone, or after other o- perations	Partial resection	No opera- tions and unknown operations in other hospitals	Total
Working full-time .....	15	1	4	20
Reduced working capacity .....	1	2	2	5
Unable to work and in bed .....	2	1	4	7
Unknown .....			1	1
Dead .....	2		1	3
Total .....	20	4	12	36

Table 3 shows their fitness for work and their condition. 20 of the 36 were fully fit for work; 3 had died. 6 were partially or completely unfit because of sinuses and pain. 1 case had tuberculosis of the hip; 1 had no sinus, but the leg was painful and weak; 1 case had renal tuberculosis.

The deaths were due to other tuberculous foci in 2, and to intercurrent disease in 1 case.

Table 3 shows that the proportion of patients found to be

fit for work was highest amongst those in whom the greater trochanter had been resected.

35 of the operations (25 total and 10 partial resections) had been performed in this hospital.

TABLE 4

*The Frequency of Recurrence after 35 Operations for Tuberculosis of the Greater Trochanter According to the Method of Operation.*

	Resec- tion	Partial Resection	No recurrence	Recur- rence	Total
1. Cases with fistulae before operation.					
a) no recurrence .....	7	1	8		8
b) recurrence .....	4	4		8	8
2. Cases without fistulae before operation.					
a) no recurrence .....	12	1	13		13
b) recurrence .....	2	4		6	6
Total .....	25	10	21	14	35

NB. Partial resection was only done in cases without radiographic evidence of bone destruction in the trochanter, and without any visible superficial bone erosion at operation.

Table 4 shows the frequency of relapse after operation. 6 out of the 25 treated by total resection, and 8 out of the 10 treated by partial resection relapsed. Partial resection had only been done in the cases in which there were no radiographic changes in the greater trochanter itself, and no sinus connected with bone could be found at operation.

#### SUMMARY AND CONCLUSIONS

A clinical and radiographic examination of 36 patients treated for tuberculosis of the greater trochanter at Martina Hansen's Hospital in the period 1936-1948 and later followed-up, showed that:

1: Most of the cases were grouped about the age 20-30 years;



the right side was affected in 21 cases and the left in 15. There were 19 males and 17 females.

- 2: Gravitation abscesses tracking in the direction of the trochanteric region and directly infecting it were found in 11 of the 36 cases; the source of these abscesses was tuberculous spondylitis in 7, and iliosacral tuberculosis in 3 cases. In these cases the disease began in the bursa of the greater trochanter, the greater trochanter itself being infected from the bursitis.
- 3: In the remaining 25 cases it is probable that the disease was brought to the region of the greater trochanter in the blood stream—the most common mode of spread of tuberculosis. In most of these 25 cases, however, the disease may have begun in the bursa, and spread thence to the greater trochanter.
- 4: In 3 cases, the tuberculosis spread from the greater trochanter to the hip-joint, in which destructive tuberculosis developed. But spread of the disease from hip-joint to greater trochanter was not observed in any case.
- 5: Sinus formation was the most common complication and was observed in 22 cases, either before or after operation.
- 6: Treatment is surgical, and should consist in the radical removal of all diseased tissue in the soft structures with resection of the greater trochanter even when only its periosteum shows visible changes. Old, scarred, and sclerotic foci in the tractus ilio-tibialis and fascia lata should be removed because of the considerable tendency of these structures to shrink and thus exert increased pressure on the bone—one of the causes, probably, of the high relapse rate. The surgical technique and the most common findings at operation are described.
- 7: Post-operative haematomata should be evacuated by repeated puncture instead of by drainage, which is an important cause of relapse.
- 9: 20 of the 36 patients were fully fit for work on re-examination. 6 still had sinuses, and 3 had died.

## RESUME ET CONCLUSION

Un examen clinique et radiographique de 36 malades traités pour tuberculose du grand trochanter à l'hôpital Martina Hansen pendant les années 1936/1948 et réexaminés plus tard a fait apparaître ce qui suit :

1. La plupart des cas se groupaient entre 20 et 30 ans ; le côté droit était atteint dans 21 cas, le côté gauche dans 15. Il y avait 19 femmes et 17 hommes.
2. Sur les 36 cas, on en a trouvé 11 chez lesquels il y avait des abcès de gravitation montrant des traces en direction de la région du trochanter et l'ayant directement infectée ; l'origine de ces abcès était une spondylite tuberculeuse dans 7 cas et une tuberculose ilio-sacrée dans 3. La bourse du grand trochanter était le siège primaire de la maladie, le grand trochanter ayant été lui-même infecté par la bourse.
3. Dans les autres 25 cas, il est probable que la maladie ait été amenée dans la région du grand trochanter par le sang, le mode le plus courant de propagation de la tuberculose. Dans la plupart de ces 25 cas, la maladie doit cependant avoir commencé dans la bourse et s'être étendue ensuite au grand trochanter.
4. Dans 3 cas, la tuberculose s'est étendue du grand trochanter à l'articulation de la hanche, dans laquelle une tuberculose destructive s'est développée. Mais on n'a observé dans aucun cas qu'une maladie de l'articulation de la hanche se soit étendue au grand trochanter.
5. La formation d'un sinus est la complication la plus courante et a été observée dans 22 cas, soit avant, soit après l'opération.
6. Le traitement est chirurgical et devrait consister dans l'enlèvement radical de tous les tissus malades des structures molles avec résection du grand trochanter même si l'on ne constate des modifications que dans son périoste. De vieux foyers cicatrisés sclérotiques dans le tractus ilio-tibialis et le fascia lata doivent être enlevés, par suite de

la forte tendance qu'ont ces structures à se contracter et à exercer alors une pression accrue sur l'os, l'une des causes, probablement, du pourcentage élevé des rechutes. La technique chirurgicale et les trouvailles les plus communes à l'opération sont décrites.

7. Un hématome post-opératif doit être évacué par des ponctions répétées plutôt que par drainage ; c'est là une importante cause de rechute.
8. Parmi les 36 malades, 20 avaient leur pleine capacité de travail au moment de la réexamination, il y avait des sinus chez 6 et 3 étaient décédés.

### ZUSAMMENFASSUNG

Die klinische und röntgenologische Nachuntersuchung von 36 Patienten die wegen Tuberkulose des trochanter major am Martina Hansen Krankenhaus in der Periode 1936—1948 behandelt und später beobachtet wurden, zeigte dass:

1. Die Mehrzahl der Fälle sich um die Jahre 20—30 gruppieren; dass die rechte Seite 21 mal und die linke 15 mal ergriffen waren. 19 Männer und 17 Frauen waren erkrankt.
2. Senkungsabscesse in die Trochanterregion mit Infektion dieser Region wurden in 11 von 36 Fällen gefunden. Der Ursprung der Abscesse war in 7 Fällen in tuberkulöser Spondylitis und in 3 Fällen in iliosacral Tuberkulose zu finden.

In diesen Fällen begann die Erkrankung in der Bursa des trochanter major und der trochantles major war von der Bursa aus infiziert worden.

3. In den übrigen 25 Fällen besteht die Wahrscheinlichkeit dass die Krankheit der Region des trochanter major auf dem Blutwegenstand — die häufigste Art der Ausbreitung der Tuberkulose.

In der Mehrzahl dieser 25 Fälle hat die Krankheit wahrscheinlich in der Bursa begonnen und hat dann auf den grossen Rollhügel übergegriffen.

4. In 3 Fällen griff die Tuberkulose vom trochanter major

auf das Hüftgelenk über, in welchem sich eine destruktive Tuberkulose entwickelte. Ein Übergreifen vom Hüftgelenk zum trochanter major wurde hingegen in keinem Falle beobachtet.

5. Fistelbildung war die häufigste Komplikation und wurde in 22 Fällen entweder vor oder nach der Operation beobachtet.
6. Die Behandlung ist eine chirurgische und sollte in einer radikalen Entfernung alles kranken Gewebes der Weichteile mit der Resektion des troch. major, selbst dann wenn nur sein Periost sichtbare Veränderungen zeigt, bestehen.  
Alle, narbige und sklerotische Herde im tractus iliio-tibialis und der fascia lata sollten entfernt werden wegen der ausgesprochenen Neigung dieser Gebilde zu Schrumpfen und dadurch einen zunehmenden Druck auf den Knochen auszuüben — wahrscheinlich eine der Ursachen für die hohe Anzahl der Rezidive. Die chirurgische Technik und häufigsten Operationsbefunde werden beschrieben.
7. Ein post operatives Hæmatous sollte durch wiederholte Punktion und nicht durch Drainage entleert werden. Es ist eine wichtige Ursache des Rezidivs.
8. 20 von den 36 Patienten waren voll arbeitsfähig bei der Nachuntersuchung, 6 hatten Fisteln, und 3 waren gestorben.

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## ON THE TREATMENT OF SACRO-ILIAC OSTEOARTHRITIS

BY

AAGE LADEHOFF

As few cases of sacro-iliac osteoarthritis treated by operation have been published in the Scandinavian literature, the following material is presented in order to illustrate the use of this more active treatment.

Since 1938, 13 out of 32 cases of sacro-iliac osteoarthritis at the Hospital of Surgical Tuberculosis at Juelsminde have been treated by operation.

Since *Sayre*, as early as 1879, reported 18 cases treated by operation there has been considerable difference of opinion on the indications for, and the results of operative treatment, as well as on the operative technique.

In 1888 *Weller van Hook* recommended early resection and osteotomy in cases with abscesses.

In 1921 *Smith-Petersen* described a special technique for intraarticular arthrodesis, and in 1926 he published with *Rogers* 13 cases of sacro-iliac tuberculosis treated by this method. The cases had been followed for 6 years; 46 % were completely cured and 23 % only partly, having persistent fistulae. Altogether, 69 % had returned to their original occupations. The prognosis was found to be worse in cases with abscesses.

*Albee* preferred to use extra-articular arthrodesis because of the risk of spreading the infection by opening a joint with an active tuberculous process.

In 1928 a committee, which had been appointed by the American Orthopaedic Association to investigate the problem, came to the conclusion that old, persistent cases could be helped, but "what to do in the cases of tuberculosis is a very great question",—and no definite conclusion was reached.

In 1934 *Pettler* reported, from a study of 31 conservatively treated cases, that in cases of destructive caseous tuberculosis 3 to 4 years are

necessary for the destructive process to be replaced on the radiographs by osteosclerosis, the formation of new bone and the appearance of normal trabeculation.

In the same year *Hald* published 4 cases of histologically confirmed ilio-sacral tuberculosis treated by Smith-Petersen's method. Examination between 9 and 12 months after operation showed all of them to be without symptoms—in only one case had an abscess developed. He recommended operation in early cases without abscess formation; cases with abscesses were more difficult and should be considered separately.

In 1937, *Tolle* compared 14 cases treated conservatively with the operated cases published in the literature, and came to the conclusion that there was little difference between the results in the two groups.

In 1938, *Thompson* published the results of 23 tuberculous cases treated by operation over a period of 18 years. Operation had been the routine treatment unless the patient's condition was so bad that radical treatment would be dangerous. 74 % of the patients were discharged from hospital as cured, and no recurrences occurred over an average observation period of 4.9 years. 5 patients died within one year of the operation. Patients who had no other tuberculous foci were discharged after 4 months' stay in hospital, while those with other active manifestations were kept in bed until the signs of activity had disappeared. The aim of the operation was to remove the focus and cause bony ankylosis: a partial resection was done.

In 1943 *Viking*, discussing the disease in detail in his monograph, reported 50 cases of sacro-iliac osteoarthritis. 7 were treated by operation, but from his material he could conclude nothing as to the value of the more radical treatment.

In 1947 *Delchef* and *de Doncker* wrote that during a period of 20 years they had diagnosed sacro-iliac osteoarthritis in 22 cases—4 of them only at autopsy—and they found that it made up 3 % of the tuberculous bone and joint affections treated. In 11 cases extra-articular arthrodesis was done, using Verral's method, the two posterior iliac spines being connected by a bone-graft from the tibia. 5 of these patients were cured, 3 died, and 3 had been followed for less than 3 months. In 7 other cases it was not possible to graft, because of the presence of sinuses with mixed infections in the sacro-iliac region and partial resections were done instead. 3 out of these 7 patients were cured, 3 died and 1 was not re-examined.

In the same year *Tavernier* and *Geay* published a brief account of a 10 years material consisting of 28 patients operated by Smith-Petersen's method. 11 of them had tuberculous sacro-iliac osteoarthritis with abscess formation, but without sinuses. Out of these 11 cases, 3 died; 3 developed fistulae post-operatively, but healed within 3 to 6 months. The patients were able to return to work between 12 and 15 months after operation.

## THE MATERIAL

This material consists of 13 patients, 6 male and 7 female.

The *symptomatology*, having been discussed in detail in the literature, will here be described in broad outline only.

The first symptom in all the patients was *pain*, described as severe low back pain or pain felt posterior to the affected joint, suggesting sciatica in about half the cases (7 had had prolonged physiotherapy without relief). The pain disappeared with rest in bed, but soon returned with movement, or on standing.

In 12 of the cases one or more *abscesses* developed, usually associated with tiredness, pain and fever (38-39° C.).

In 75 % of these cases with abscess formation *sinuses* appeared, either spontaneously or after aspiration or incision.

The signs were: slight *limp*; moderate *muscle atrophy* of the lower limb; and positive *Lasègue's sign* at about 50°; *pain in the joint on indirect pressure* occurred in about half the cases.

All the cases showed *radiographic* pictures which were diagnostic: a typical osteoarthritis with increased joint space, irregular outline of the articular surfaces, and varying degrees of destruction of the sacral and iliac alae. In 4 cases there was 3-5 mms. upward dislocation at the symphysis on the affected side.

Fig. 1 shows the typical radiographic changes in a left sacro-iliac joint.

In all cases but one the affection was unilateral.

The *etiology* was tuberculous in 7 cases (group 1), pyogenic in 5, and non-specific degenerative, with allergic manifestations in other joints, in 1 case (group 2).

*Group 1.* 3 males and 4 females; the average age at onset of symptoms was 24.5 years, thus coinciding with the appearance and closure of the sacral and iliac epiphyseal lines. As a matter of fact the sacro-iliac joint is rarely the site of inflammation after the age of 30—if it is affected, it is usually





Fig. 1.

involved by direct spread of an abscess or granulation tissue from a tuberculous osteomyelitis of the dorso-lumbar spine. This is certainly due to the degenerative changes which affect the joint with increasing age and result in bony ankylosis. *Sashin* described these age changes after examining the sacroiliac joints of 257 autopsies on cases dying from other conditions.

In 4 patients the *route of entry* was pulmonary; in 3 of these a pleuritis serosa was the first tuberculous manifestation; 3-4 months later the joint affection was indicated by pain, and after a further 3-5 months an abscess appeared. Thus the osteoarthritis appeared clinically soon after the tuberculous primary infection, which is assumed to be closely related to the time of development of the pleurisy.

In 3 cases the route of entry could not be determined.

2 patients had other active tuberculous foci: 1 of them had a mild tuberculosis of the hip and 1 a sputum-negative pulmonary tuberculosis.

The interval between onset and operation varied between 9 months and 4 years, with an average of 2.4 years.

Abscesses were present at the time of operation in 6 cases, 4 of these had had sinuses for 4-18 months; in 1 the fistula had been closed for 1 month after a long course of treatment with penicillin, but had re-opened.

The site of the abscesses and the number of fistulae are shown in the following table:

Site of abscess	Sinus
Iliac fossa .....	0
" " .....	0
" " + gluteal region + intrapelvic. ....	2
" " + trochanteric region .....	2
" " + lumbar region .....	2
Lumbar region .....	1

Tuberculosis (human type) was verified in 6 cases, either bacteriologically, by culture and inoculation of pus or material from the focus, or histologically, by examination of the latter.

In the remaining case, where there was no abscess, a necrotic, calcified focus was found; histologically there was no evidence of tuberculosis and no tubercle bacilli or other pathogenic bacilli could be cultured, but the slow course of the disease over 4-5 years and the simultaneous tuberculosis of the hip are strongly suggestive that the condition was tuberculous.

In all 7 cases the Mantoux I test (0.01 mg.) was positive (at least 10 mm.).

The *pre-operative treatment* consisted of "general sanatorium cure" to restore the general condition, and universal carbon arc-light baths, whose importance we believe to be mainly as a skin-disinfected and consequently as a preventative of mixed-infection in fistular cases.

If the patient had not previously had adequate conservative treatment he lay in a plaster bed extending from the lower thorax to the toes, for 9-16 weeks, in order to abolish the

pain by relaxing the lumbar and gluteal spasms and to immobilise the joint and thus rest the affected area.

Cases of mixed-infection, with intermittent periods of fever, raised staphylococcal and anti-streptolysin titres, and "other bacteria" in the pus from the copiously discharging sinuses, were intensively treated with sulfathiazole or penicillin according to the chemotherapeutic sensitivity of the bacteria.

The abscesses were aspirated frequently, and always immediately before operation.

The time for operation was decided by consideration of the patient's general condition, the temperature chart, the sedimentation rate, and the radiographs.

The *post-operative treatment* was essentially as the pre-operative. 7-12 weeks after operation the patient was taken out of his plaster bed and began to get up.

1 patient with sinuses died 24 hours after operation from a rapid sepsis due to mixed-infection. This death might certainly have been avoided if the antibiotics now in use had been available at that time (1942)—and it serves to emphasise the need for effective pre-operative treatment of mixed-infection.

After operation the abscesses re-appeared slowly, if at all. The sinuses gradually ceased to discharge and healed within 3-10 months. 1 case developed an abscess in the gluteal region 1 year after operation; it healed after incision and there has been no further abscess or sinus for 4 years.

When the fistulae were healed, the patients were discharged and told to spare themselves for the first few months out of hospital.

The average stay in hospital was 10 months ( $5\frac{1}{2}$ -19 months).

Two patients were able to return to full work 3 months, one 6 months, and three from 12 to 18 months after discharge from hospital.

The patients have been followed for an average of 3 years (6 months to 6 years) after operation; all are able to work and all the sinuses remain healed. In 1 case, a woman, a sinus



Fig. 2.

developed from a tuberculosis of the spine 2 years after operation, but the sacro-iliac disease was then, and is still—4 years after operation—healed, both clinically and radiographically (see fig. 2, same case as fig. 1).

At re-examination the only complaints were of "a little tiredness across the low back and in the operation scar" after prolonged hard work.

Examination showed slight atrophy of the thigh (1-3 cm.), and in one case slight stiffness of the affected side. Lasègue's sign was negative, though in 2 cases there was slight tightening of the muscles at 60°. There were no radiographic signs of activity at the site of the focus.

*Group II.* 3 males and 3 females; the average age at onset of symptoms was 19.7 years.

The 5 cases of pyogenic osteoarthritis all were abscess-forming with either constant or intermittent discharge for

18 months to 24 years, with periods of fever, pus retention and subsequent increased discharge.

The pre- and post-operative treatments were essentially the same as in Group I.

There was one death: the patient who had had for 11 years a discharging staphylococcal osteoarthritis of the sacro-iliac and hip joints died of sepsis 4 years after operation; the sinuses had never healed. As in the case already mentioned in Group I, the outcome might probably have been different if effective chemotherapeutic drugs had been available at that time.

In 3 of the patients the sinuses closed respectively  $1\frac{1}{2}$ ,  $2\frac{1}{2}$ , and 3 years after operation, and have remained healed since, for between  $2\frac{1}{2}$  and 4 years. The patients are able to work and are clinically cured; radiography shows healing with ankylosis of the joint.

The case with disease of both sacro-iliac joints and bilateral abscess formation, with sinuses for  $3\frac{1}{2}$  years, was treated by partial resection of the worse side; the intention was to operate also on the other joint, but 18 months after the first operation there was both clinical and radiographic healing, and the sinuses were soundly healed, so that no further operation was done.

1 patient had had a discharging staphylococcal osteomyelitis of the right ilium with involvement of the sacro-iliac joint for 24 years. A partial resection of the joint and of the posterior  $\frac{1}{4}$  of the iliac crest was done. After prolonged penicillin therapy she was discharged, 2 years after operation; only 2 of the numerous profusely discharging sinuses remained, and only occasionally a few drops of pus were discharged. Now, 9 months later, these 2 fistulae are closed after 3 week's treatment with streptomycin.

The remaining patient, a woman aged 35 years, had for 8 years had periodic disabling sciatica as the only symptom of a left sacroiliac disease; there had never been an abscess. Further, there was a mild arthritis with serous effusion of both knees, the right shoulder and right elbow. The sedimen-

tation rate was slightly raised; the staphylococcus anti-toxin and antistreptolysin titres were within normal limits; the Mantoux I was positive.

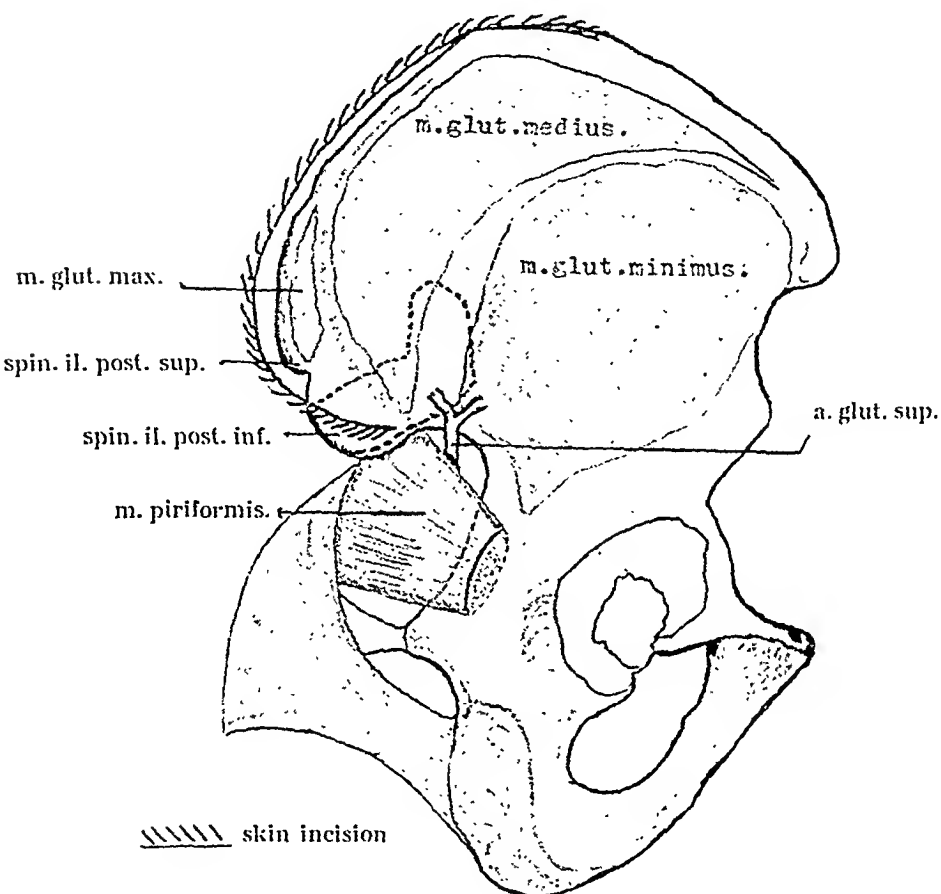


Fig. 3.

At the operation degenerative cartilage and necrotic bone were found; both bacteriological and pathological examinations were negative; no bacteria were cultured, and histologically there was only a serous effusion into the marrow spaces and formation of oedematous connective tissue.—The wound healed on the 12th. day.—9 months later, there was bony ankylosis, and now,  $3\frac{1}{2}$  years later, the patient has still no pain, and in addition the signs and symptoms in the other joints have disappeared.

One must assume this case to have been a non-specific serous sacro-iliac osteoarthritis with secondary allergic, effusive reactions in other joints, as there were no radiographic bone changes and culture of fluid from the joints was negative.

The Wassermann, Gono and Widal tests were negative in all 13 patients.

The *surgical technique* used is described briefly here:

A curved incision is made along the posterior part of the iliac crest, and carried behind the upper posterior iliac spine and downwards and forwards across the lower posterior iliac spine to the sciatic notch. Here the muscles and ligaments are detached to give a mass of skin and muscle which is pulled down together with the superior gluteal artery, which is carefully preserved. When the ilium is exposed the sciatic notch and the two posterior iliac spines serve as guides; the bone anterior to the latter carries the joint surface on its medial side, and access to the joint is obtained by chiselling it open.—Fig. 3 is a diagram of the skin incision and the anatomy.

Granulation tissue and all bone and cartilage which appears to be pathological is scraped away. The cavity thus produced is drained by a rubber drainage-tube, and the wound is sutured in layers.

In one case intra-articular arthrodesis was also done by inserting a bone-graft from the ilium.

"Primary healing" occurred in 3 cases; in the remainder the site of the drainage-tube healed within 11-20 weeks.

The aim of the operation is twofold: to remove the focus of the disease, thus preventing further destruction and abscess and sinus formation, and to ankylose the joint, thus reducing the risk of recurrence. Both these aims are attained by only partial resection.

That ankylosis takes place is shown both clinically by the absence of pain, and radiographically by a more or less complete bony union between the joint surfaces within 3-6 months.

Fig. 4 shows the radiographs of the same patient as in Fig. 1 3 months after operation. The operation defect can still be seen; 4 years later it is reduced by  $\frac{1}{3}$  (Fig. 2).

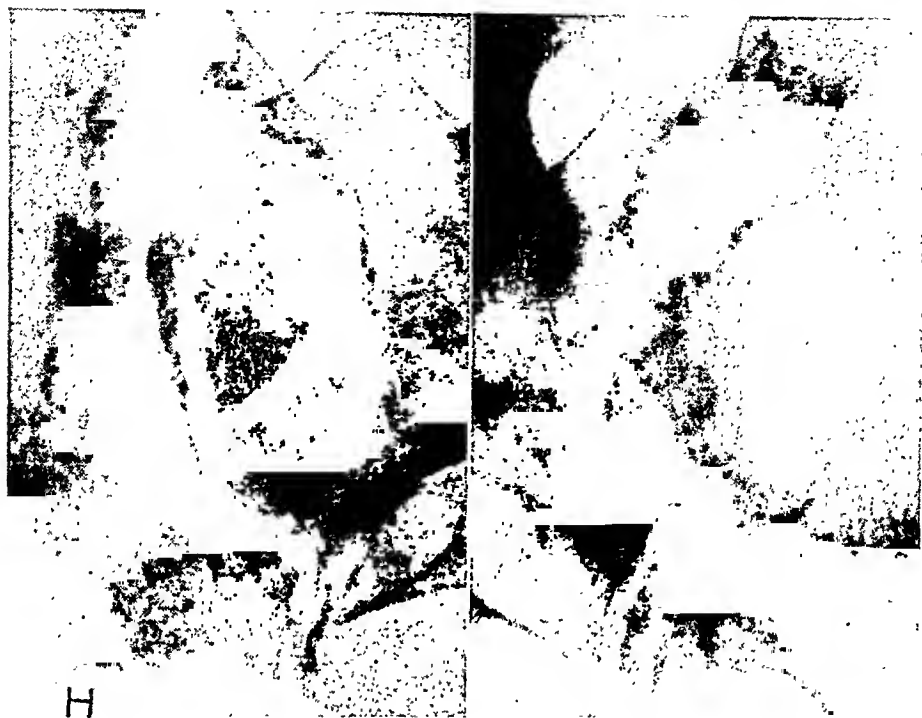


Fig. 4.

Although the number of cases treated has been rather small it may be justifiable to set out the following *indications for operation* in cases of sacro-iliac osteoarthritis, of both tuberculous and pyogenic etiology:

- 1) if the sacro-iliac disease is either the only or the main active focus, and abscesses re-appear in spite of repeated aspiration and adequate conservative treatment for 3-4 months.

- 2) if there are sinuses which show no tendency to healing after several months' conservative treatment.

- 3) in cases of caries sicca with continued pain and consequent inability to work.

The danger of pyogenic sepsis is insignificant with modern chemotherapy; similarly a general tuberculous spread, which is very rare and too much feared, following interference with a tuberculous focus may be prevented or stopped by streptomycin.





Fig. 5.  
On admission.

Exclusively conservative treatment should be used in tuberculous cases, when there are other foci of bone or viscera which require a long conservative treatment, so that an operation on the sacro-iliac joint will not hasten the patient's return work.

In conclusion, the following report is given of a *typical* case:

A small-holder, aged 25 years, developed pain across the right loin and down the back of the right thigh in Dec. 1946 (2-3 months after the appearance of a left tuberculous pleurisy with effusion).

He was admitted to hospital in Feb. 1947 and treated for 2 months by rest in bed, heat, and massage for lumbar-gluteal myositis, but there was no improvement.

Further examination of the radiograph of 17.2.47 showed that at that time there were already signs of disease in the right sacro-iliac joint, the joint space being increased, with blurred outlines of the joint surfaces.

Radiography of the lungs showed no abnormality beyond a small

area of calcification the size of a pea in the left lung. Tubercle bacilli had never been found in the gastric contents.

In Aug. 1947 there was increasing pain, and an abscess developed in the right inguinal region; tubercle bacilli were cultured from the contents of the abscess.



*Fig. 6.*

7 months after operation.

Radiography on 29.9.47 showed irregular destruction of the R. sacro-iliac joint (Fig. 5), and urography showed medial displacement of the R. ureter by a shadow which suggested an abscess.

On admission here, 17.11.47, an abscess the size of an egg could be felt in the R. inguinal region; the Lasègue test was positive at 60°; there was 1 cm. wasting of the R. thigh and leg; the sedimentation rate was 28 mm.; Mantoux I was positive.—No other abnormalities were detected.

The patient was kept in a plaster bed for 8 weeks and was given carbon arc-light treatment. The abscess was aspirated twice, and 15 ml. pus were obtained; a sinus developed at the puncture site. On 26.1.48 a

partial resection of the joint was performed, using the technique described above. The joint was found to be filled with necrotic bone and cartilage and abundant granulation tissue communicating by a track, as wide as a finger, with the abscess. The operation and post-operative course were uncomplicated. The drain was removed on the third day and the sutures on the 10th day, at which time the wound was healed. Material removed at operation showed tuberculous pathology histologically, and tubercle bacilli (human type) were cultured from it. The abscess was aspirated twice, and the sinus healed 9 weeks after operation, at which time the patient was allowed up; for 3 weeks there was some difficulty in walking.—While in hospital he had repeated attacks of R. renal colic with macroscopic blood and renal calculi in the urine.

The patient was discharged well on 28.5.48 (4 months after operation).

At re-examination 26.8.48 (3 months after discharge) there were no complaints beyond a sensation of "pulling" in the operation scar, after walking 4-5 km. The sinus had discharged one small drop 4 weeks previously, but had otherwise remained healed.—No abnormal signs were found; the operation scar was soundly healed. The patient was allowed to begin working. Radiography (Fig. 6) showed good calcification, trabecular bone structure, and bony ankylosis above.

Thus, 19 months after the first symptoms of tuberculosis of the sacro-iliac joint, the patient may be considered to be cured, after 6½ months in hospital.

### SUMMARY

The literature on the treatment of sacro-iliac osteoarthritis is briefly reviewed. The author reports 13 cases treated by operation; 7 were tuberculous, 5 pyogenic, and 1 a non-specific degenerative arthritis. Abscesses developed in 12 of the cases, and 9 had one or more sinuses before operation.

The pre- and post-operative treatments are described. Special importance is attached to the prophylaxis and effective chemotherapeutic treatment of mixed-infection in cases with sinuses.

The operation used was a partial resection, which is described in outline.

11 patients were cured, 2 died from sepsis at a time when the present antibiotics were not known.

The indications for operation are described.

In conclusion, a typical case is reported.

## RESUME

La littérature publiée sur le traitement de l'ostéoarthrite sacro-iliaque est sommairement passée en revue. L'auteur rapporte 13 cas traités chirurgicalement: 7 étaient tuberculeux, 5 pyogènes et 1 arthrite dégénérative non spécifique. Des abcès s'étaient développés dans 12 de ces cas et chez 9 il y avait un ou plusieurs sinus avant l'opération.

Les traitements pré et post-opératoires sont décrits. Une importance spéciale est attachée à la prophylaxie et à un traitement chimiothérapeutique efficace des infections mixtes dans les cas avec sinus.

Comme opération on a pratiqué une résection partielle, décrite dans les grandes lignes.

11 malades ont été guéris, 2 sont décédés à la suite d'infections, à une époque où les antibiotiques n'étaient pas encore connus.

Il est donné la description des indications des cas à opérer. En conclusion, un cas typique est rapporté.

## ZUSAMMENFASSUNG

Eine kurze Übersicht der Literatur über die Behandlung der sacro-iliakal Osteoarthritis wird gegeben. Der Verfasser berichtet über 13 Fälle, die operativ behandelt wurden. 7 waren tuberkulös 5 pyogen und ein Fall zeigte nicht spezifische degenerative arthritis. Abszesse entstanden in 12 der Fälle, und 9 hatten eine oder mehrere Fisteln vor der Operation.

Die prä und postoperative Behandlung wird beschrieben. Besondere Wichtigkeit wird der Prophylaxe und der wirksamen chemotherapeutischen Behandlung von mischinfizierten Fällen mit Fisteln beigemessen.

Die angewendete Operation war eine teilweise Resektion, welche in grossen Zügen beschrieben wird.

11 Patienten wurden geheilt, 2 starben an Sepsis zu einer Zeit in der die nunmehr verfügbaren Antibiotica noch nicht bekannt waren.

Die Indikationen der Operation werden beschrieben. Zum Schluss wird ein typischer Fall aufgezeigt.

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## PARTIAL SYNOVECTOMY OF THE KNEE JOINT

BY

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For more than fifty years synovectomy, either partial or complete, has been performed in cases of chronic hydrops of the knee joint. Only during the past 20-25 years, however, has this operation been used on a large scale, and it has been mainly through the work of *Swett* that synovectomy has become more widely known. Over a number of years a fairly large number of results have been published. On the whole, the results are reported to be good, but in some publications either the time of observation has been too short or the material has been too small to allow a satisfactory estimation of the late results.

Persistent hydrops has been thought to be due either to occlusion of the paths of drainage from the knee joint, or to faulty resorption due to various pathological changes. The aim of synovectomy has been to create new resorption paths. Since drainage takes place mainly through the suprapatellar bursa (*D. H. Kling, Mayeda*, and others) surgery has usually been confined to extirpation of this bursa (partial synovectomy).

A large number of experimental investigations have been made in attempts to throw more light on the problem of disturbed resorption, and a vast literature has been published on the subject. Only publications that can be of interest in the present study will be mentioned here. *Bauer et al., Efskind*, and others found that protein substances are only, or mainly,

resorbed through the lymph channels, whereas the crystalline substances are resorbed through the blood channels (*Efskind, Kuhns*).

*Gerota* and *Notkins* demonstrated that the possibilities of resorption from the joint are decreased in inflammatory synovitis. *Kuhns* considered that he could show experimentally that the possibilities for the resorption of particles larger than the size of one molecule are diminished in inflammatory changes in the joint, whereas resorption returns to normal when these changes have regressed. A persistent irritative condition causes a decrease in the resorptive function of the lymphatic vessels (*Kuhns*). According to *Efskind*, lymphatic drainage is decreased in pyarthrosis and for a time after total synovectomy. He also believed that there was a transient decrease in the resorption capacity after uncomplicated arthrotomy. Others, e.g. *Rostock*, believe that in empyema of the knee joint there is a rapid increase in the power of resorption, which is more effective than with aseptic exudate. *Efskind* performed clinical resorption experiments with perabrodil and indigo carmine (crystalline substances) and found that their resorption was decreased after total synovectomy and in pyarthrosis. A number of writers (*J. A. Key, W. Bauer et al.*) believe that an active phagocytic resorption of attrition products from the joint cartilage and the synovia occurs. The experimental investigations are less convincing, as they were performed on animals, whose knee joints are neither anatomically nor functionally similar to those in man. Further, the substances used were foreign to the organism and cannot, therefore, be considered to show the physiological conditions in man.

It is probable that hydrops has been regarded too much as a problem of resorption. We have very little definite knowledge of how either the normal synovia is formed or the pathological exudate takes place, but it is just as reasonable to regard a morbid increase of fluid in the joint as the result of an increased rate of formation of joint fluid as of impaired resorption.

Many writers have stressed that at present no definite

rules can be laid down for the indications for synovectomy, and that the cases should be selected carefully (*Allison, Bernstein, Speed, Swell* and others). Since our knowledge of the physiology and pathology of the knee joint is very incomplete, the decision regarding synovectomy must depend entirely on the surgeon's experience and view of the individual case. *Bernstein's* statement that "no rules can be established for the performance of synovectomy" can be considered as representing the general opinion on the indications for this operation. The results of synovectomy must be judged against this background.

#### THE WRITER'S MATERIAL<sup>1</sup>

The material reported here consists of 36 partial synovectomies performed on 34 patients (18 males and 16 females). The average age at operation was 35 years. Table I shows the duration of the disease and the observation period.

In order to assess the results found at follow-up examina-

TABLE I

	Polyarthritis 14 patients; 15 synovectomies	Cases of unknown or uncertain origin 20 patients; 21 synovectomies
Average duration of disease before operation . . . . .	5.0 years	5.6 years
Average age at operation . . . . .	37.8 years	32.8 years
Average time between operation and follow-up examination . . . .	4.4 years	5.9 years

<sup>1</sup> The material derives from the Orthopaedic Clinic (Head: Professor S. Friberg) of Karolinska Institutet, Stockholm, the Orthopaedic Clinic (Head: Professor G. Wiberg) in Lund and from Vanförcanstalten (Head: Dr. H. Camitz, M.D.) in Gothenburg. I wish to express my thanks to the Heads of the respective Hospitals for their kindness in placing the material at my disposal.



tion it is important to try to classify the material according to aetiology. One group, i.e. cases with chronic polyarthritis, can be distinguished from the rest with a fair degree of certainty. The rest are probably heterogeneous as regards aetiology. The aetiology will be considered further when the cases are discussed.

Guinea-pig tests and bacterial cultures of the exudate were done on practically every case, but the results were uniformly negative.

Since the patients came from all parts of the country, it was not possible for the writer to follow-up each case personally. A questionnaire was therefore sent to each patient, the questions being formulated so that there would be no difficulty in giving a correct answer. All except two patients answered. 16 patients were examined personally by the writer, in a few cases on several occasions. Since many of the patients—usually those with polyarthritis—were treated at other hospitals after operation, the statements made in reply to the questionnaire could be checked.

### *Operative Technique.*

Partial synovectomy, consisting of extirpation of the suprapatellar bursa, was performed on all the cases. As several different surgeons operated, the technique was not always uniform in individual details. The incision was either a lateral or a medial parapatellar incision. The writer personally prefers the former, which affects the muscle less than the medial incision. With the latter it is impossible to avoid injury to the vastus medialis, which extends further distally than the vastus lateralis.—The suprapatellar bursa can be easily peeled out bluntly, with the exception of the anterior aspect, where it is nearly always closely attached to the tendon of the rectus femoris muscle.

After synovectomy, synovial cells reappear, presumably by metaplasia of the subsynovial tissue components (*Segale, J. A. Key, Walcott* etc.). Regeneration appears to take place fairly rapidly. According to *Segale*, it is completed 21 days after partial synovectomy. *Swett* found in two cases “a re-

TABLE II  
Cases With Polyarthrititis.

Case	Sex	Age at onset	Age at operation	Time of observation in years	Primary result of operation	Result of operation at follow-up	Comments
1. O.F.N.J. G <sup>1</sup> 12889	♂	27	36	5	Exudate	Exudate	Both knee joints affected. S.R. before op. 5 mm/1 hr. 1 yr. after operation exudate still present. No pain.
2. A.J. G 13190	♀	32	48	5	Exudate	Exudate	Both knee joints affected. S.R. before op. 27 mm/1 hr. 6 mths. after op. exudate still present. Doing full-time housework. No pain.
3. O.F. G 15338	♂	46	51	7	No exudate	No exudate	Most limb joints affected. Unable to return to former work (heavy manual labour).
4.* J.B. G 18602	♂	40	41	9	Exudate	Exudate	The knee joints mainly affected. S.R. before op. 10 mm/1 hr. No pain. Suggestion of flexion contracture.
5. N.N.P. G 24736	♂	19	26	5	Exudate	No exudate	Most limb joints affected. S.R. before op. 30 mm/hr. Pain after operation.
6. S.S.S. G 24083	♀	40	46	7	Exudate	Exudate	Most limb joints affected. S.R. before op. 32 mm/hr. Pain and flexion contracture. 4 yrs. after synovectomy, arthrodesis of the knee joint. Severely invalidated.

TABLE II (cont.)

Case	Sex	Age at onset	Age at operation	Time of observation in years	Primary result of operation	Result of operation at follow-up	Comments
7 a. K.G.B. G 27448	♂ Right knee	11	14	5	Exudate	No exudate	Knee and ankle joints affected. S.R. before 1st op. 14 mm/hr. 6 mths. after operation exudate still present in right knee, left knee: N.A.D. No pain.
7 b. K.G.B. G 27448	Left knee	»	»	»	Exudate	No exudate	
8. K.L. L 511 40	♀	23	34	5	Exudate	Exudate	Knee joints mainly affected. S.R. before op. 5 mm/1 hr. Intermittent pain.
9. K.G.B. G 29983	♂	31	40	4	Exudate	Exudate	Both knee, hand and ankle joints affected. Pain in knee. Unable to walk without stick.
10. I.L.P. L	♀	21	26	2	Exudate	Exudate	Knee and ankle joints affected. S.R. before op. 25 mm/1 hr. Pain in knee.
11. E.G. L 564/42	♀	31	34	3	No exudate	No exudate	Nearly all limb joints affected. S.R. before op. 56 mm/hr. No pain in knee. <i>n.b.</i> Synovectomy + extirpation of the patella.

TABLE II (cont.)

Case	Sex	Age at onset	Age at operation	Time of observation in years	Primary result of operation	Result of operation at follow-up	Comments
12. J.B.B. S 4765/42	♂	51	56	3	No exudate	No follow-up examination	S.R. before op. 15 mm/hr.
13. T.L. L 209/42	♂	27	29	3	No exudate	Exudate	Most limb joints affected. S.R. before op. 72 mm/hr. Pain in operated knee with change in weather. Not working, owing to involvement of other joints.
14.* N.M. L 370/43	♀	50	57	2	No exudate	No exudate	Most limb joints affected. S.R. before op. 8 mm/hr. Discomfort from knee constant after operation.

\* L and G in the first column denote whether the patient was treated at the Orthopaedic Clinic in Lund or at the Vanförestalt in Gothenburg.

\* = Follow-up examination made personally by the writer.

placement of synovial membrane with no evidence of scar-tissue" after "several months".

#### *Cases With Chronic Polyarthritis (table II).*

This group comprises 14 patients (15 synovectomies). 13 patients (14 synovectomies) were followed up. A detailed account of the cases or case-histories of the individual patients is of little interest; all showed the classical symptoms of polyarthritis. Table II shows some relevant data. Synovectomy had in every case been preceded for many years by various treatments at special hospitals for rheumatic diseases.

If the *primary* results of operation are considered<sup>2</sup>, it is found that only 5 of the 15 synovectomized knees became free from exudate. A further 3 cases (amongst them the patient with bilateral hydrops) became free from exudate during the period between operation and follow-up examination, whereas one case, which had primarily been free from exudate had relapsed.

Thus at the *follow-up examination* only 6 cases were free from exudate (one patient was not examined), i.e. approximately 40 per cent. These results agree fairly well with those of *Inge* for synovectomy in chronic polyarthritis. In 26 of *Inge's* cases, which had an average age of 37.1 years at operation and an average observation time of 5.6 years (thus comparable with the material reported here), the results of the operation were good in only 50 per cent of the cases. Other reports point in the same direction (*Boon-Itt*, *Massarol*, and others).

For many reasons it would seem inadvisable to operate during the active stage of the condition; but in cases of polyarthritis it is difficult to find the best time for synovectomy. The progression and regression of the disease may be followed by the sedimentation rate, and it is tempting to assume that patients who have had a low sedimentation rate for a long time, so that the disease can be presumed to be in a regressive state, would be more suitable subjects for operation than those with high rates, suggesting active infection. Examination of the cases in the present series showed that of the 9 cases *with hydrops* immediately after the operation, 5 had normal or only slightly raised sedimentation rates immediately before operation and 4 had considerably raised rates<sup>3</sup>. Of the 4 cases *without hydrops* immediately after synovectomy, 2 had normal or subnormal rates and 2 very high rates pre-operatively<sup>4</sup>. (In 2 patients the sedimentation rate had not been measured).

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<sup>2</sup> The term "primary results of operation" covers the condition during the months immediately following the operation.

<sup>3</sup> Cases 1, 4, 7a and b and 8, and Cases 2, 5, 6, and 10 respectively.

<sup>4</sup> Cases 12, 14 and 11, 13 respectively.

*Follow-up* examination showed that of the patients *with hydrops*, 3 had had low sedimentation rates before operation, and 4 had had very high rates. Of the 6 cases which were *free* from exudate at the *follow-up examination*, the sedimentation rate had been normal in 3 and raised in 2 (one case was not re-examined). Although there are only a few cases in each group, the figures show that the *sedimentation rate need not greatly influence the decision regarding synovectomy in cases of chronic polyarthritis*.

The age at onset and duration of the disease showed no appreciable differences in the cases with and without post-operative exudate, nor did the extent of the disease appear to affect the prognosis. Both cases with involvement of only a few joints, and cases in which practically all the joints of the limbs showed pathological changes, were equally represented amongst those with and without post-operative hydrops.

Unfortunately, the knee joint was examined radiographically before operation in only 6 cases<sup>5</sup>. In case 7, radiography two years before synovectomy showed slight bilateral calcium reduction. There was a primary post-operative exudate in both knees, which was not present at the follow-up examination. Cases 11 and 12 were examined radiographically 2 and 4 years respectively before synovectomy; both had a severe arthrosis deformans with reduced joint space and osteophytes. In case 11 there was never any exudate after operation. Case 12 was not followed up. Cases 8, 9 and 13 (radiography 5, 1 and 2 months respectively before operation) showed moderate arthrosis deformans with insignificant reduction of the joint space. In cases 8 and 9 the exudate persisted after operation, whereas in case 13 there was no primary post-operative exudate although it occurred later.

It is not possible to make any definite statements on the relation between the radiographic picture and the results of synovectomy. However, severe deformans changes present several years before operation need not prevent good results:

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<sup>5</sup> Cases 7a and b, 8, 9, 11, 12 and 13.

thus case 11, which had such changes two years before operation had good primary and final results.

It is obvious that post-operative treatment will have a considerable effect on the final result. This is particularly true of cases in which exudate has been present for a long time and has caused reduced function of the knee and atrophy of the quadriceps muscle, with quadriceps insufficiency. Great importance has therefore been attached to beginning quadriceps exercises as early as possible after operation. In 7 cases the knee was immobilized in a circular plaster cast for two weeks after operation, and then the usual physiotherapy was begun. In the remaining cases the knee was not immobilized in a plaster, and physiotherapy was begun 1-2 weeks after operation. However, no conclusion can be made here on the relative advantages of the two methods.

Full flexion and extension was obtained after operation in 5 cases<sup>6</sup>. Of these, 3<sup>7</sup> had 5-10° loss of extension and 20-30° loss of flexion before operation. Thus, the range of movement in these cases was increased after synovectomy. However, *in all the other cases the range of movement was decreased*. In one case (Case 11) this might be explained by the fact that the patella was also excised at the time of the synovectomy. In all the remaining cases there was 5-10° loss of extension for six months to one year after the operation, though there had been full extension before operation. 3 of the 5 cases with satisfactory range of movement had been in plaster after the operation.

In judging the patient's disability after the operation, one must recognize that polyarthritis in its more pronounced forms is a very disabling disease. In the 6 cases<sup>8</sup> in which the patient was nearly or completely disabled, nearly all the joints of the limbs were involved. In the remaining cases the disease was localized to a few joints and was usually milder.

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<sup>6</sup> Cases 1, 7a and b, 8 and 14.

<sup>7</sup> Cases 1, 8 and 14.

<sup>8</sup> Cases 3, 5, 6, 9, 11 and 13.

The excised synovia was examined histologically in every case. The histological picture was uniform and showed the usual signs of a chronic inflammation without specific changes.

Thus, the results are extremely capricious, and synovectomy should only be used sparingly in patients with chronic polyarthritis, and then only in cases where the course of the disease has been mild, only a few joints have been affected, and the patient is not an invalid. *The marked tendency of the disease to relapse is presumably the cause of the relatively poor results of partial synovectomy in patients suffering from polyarthritis.*

#### *Cases With an Uncertain or Unknown Origin (Table III).*

This group, which for the sake of brevity will be called here "the hydrops group", comprises 21 synovectomies performed on 20 patients (10 males and 10 females). Tables I and III show the duration of the disease, the average age at operation and the length of the observation period.

As mentioned earlier, this group is aetiologically very heterogeneous. In addition, the treatment has varied; in 9 cases pathological patellar cartilage was excised as well as synovia.

The patients in the hydrops group had as a rule no discomfort from the joint. Some of them said that the exudate increased on exertion, but most said that it had remained unchanged for a long period. There was full range of movement, and the patients were to a great extent able to carry out their usual work. As in the previous group various kinds of conservative treatment had been attempted without success. In addition, in most cases the joint had been aspirated repeatedly.

Trauma was stated to have caused the exudate in 7 cases (Cases 1-7 in table III), the exudate being said to have followed a definite trauma and persisted until operation. However, the diagnosis of "traumatic synovitis" should be made with some reserve, since, even though it certainly occurs, it is always possible that changes were already present, though



TABLE III

*Hydrops of Uncertain or Unknown Origin.*

The cases marked with \* were examined by the writer.

Case	Sex	Age at onset	Age at operation	Time of observation	Primary result of operation	Result of operation at follow-up	Comments
1.* O.S.V.K. S 4226/37	♀	26 yrs.	29 yrs. Synovectomy + chondrectomy (right knee)  31 1/2 yrs. Extirpation of patella (right knee)	10 yrs.	Exudate	(No exudate)	1 1/2 years after operation constant discomfort since operation. 2 1/2 yrs. after first operation: excision of patella: much cartilage on patella lacking. 1944 (7 yrs. after synovectomy) polyarthritis after scarlatina with involvement of operated knee amongst other joints. Follow-up examination: subjective discomfort, 5-10 degrees flexion contracture. Some hydrops. <i>Radiography</i> , before op.: N.A.D.; at follow-up examination; severe arthrosis deformans.
2.* K.V.S. S 34109	♀	19 yrs.	23 yrs. Synovectomy + chondrectomy (left knee)	11 yrs.	No exudate	No exudate	One knee becomes slightly tired. Otherwise no symptoms. Marked subpatellar crepitations. Otherwise N.A.D. <i>Radiography</i> , before op.: slight decalcification; at follow-up examination: N.A.D.
3.* E.A.P. S 5145/40	♀	34 yrs.	36 yrs. Synovectomy + chondrectomy (right knee)	5 yrs.	No exudate	No exudate	No symptoms or signs. <i>Radiography</i> , before op.: N.A.D. Follow-up examination: slight accentuation of the joint contours.

TABLE III (cont.)

Case	Sex	Age at onset	Age at operation	Time of observation	Primary result of operation	Result of operation at follow-up	Comments
4. K.E.L. S 2020/40	♂	24 yrs.	27 yrs. Synovectomy (left knee)	3 yrs.	Exudate	No exudate	No symptoms or signs. <i>Radiography</i> , before op.: N.A.D.
5.* D.V. S 879/40	♀	30 yrs.	31 yrs. Synovectomy (right knee)  33 yrs. New synovectomy (right knee)	4 yrs.	Exudate	(No exudate)	For 2 yrs. after second synovectomy intermittent exudate lasting for 2-3 days with intervals of 2 weeks free from symp- toms. No connexion with menstruation. Then free from symptoms for 1 yr. following x-ray treat- ment, but the same symp- toms appeared in the non-operated knee. <i>Radiography</i> , before op.: and at follow-up: N.A.D. <i>Follow-up examination</i> : no pathological signs or symptoms.
6.* S.B.A. S 3491/37	♂	20 yrs.	25 yrs. Synovectomy (right knee)	5 yrs.	No exudate	No exudate	At age of 20, biopsy ar- throtomy right knee. 2-3 yrs. after synovectomy, discomfort from knee. <i>Follow-up examination</i> : for last 2 yrs. no symp- toms. Plays games. Signs: slight quadriceps atrophy, otherwise N.A.D. <i>Radiography</i> , before op.: N. A. D.; at follow-up ex- amination: moderate ar- throsis deformans.
7. J.S. L 298/42	♂	35 yrs.	36 yrs. Synovectomy (right knee)	3 yrs.	No exudate	No exudate	No symptoms or signs. <i>Radiography</i> , before op.: arthrosis deformans; 1 yr. later, considerable pro- gression of this condition.

TABLE III (cont.)

Case	Sex	Age at onset	Age at operation	Time of observation	Primary result of operation	Result of operation at follow-up	Comments
8. E.A.B. S 31219	♂	31 yrs.	37 yrs. Synovectomy + chondrectomy (right knee)	7 yrs.	No exudate	No exudate	Pain at times. Marked subpatellar crepitations. <i>Radiography</i> , before op.: diffuse decalcification in right knee. Left knee N.A.D.
9.* H.E.A. S 4958/40	♂	49 yrs.	51 yrs. Synovectomy (left knee)	6 yrs.	No exudate	No exudate	No symptoms. Knee slightly deformed with some thickening of the capsule. Subpatellar crepitations. <i>Radiography</i> , before op.: slight decalcification; at follow-up examination: fairly severe arthrosis deformans.
10. N.Ch.K. S 1139/40	♂	18 yrs.	26 yrs. Synovectomy (left knee)	5 yrs.	Exudate	Exudate	No pain. Repeated exudate after puncture after operation. <i>Radiography</i> , before op.: N.A.D.
11.* K.E.P. S 2834/40	♂	35 yrs.	36 yrs. Synovectomy + chondrectomy (right knee)	7 yrs.	No exudate	No exudate	At age of 20, op. for free joint bodies in right knee. Knee felt somewhat weaker after op. Otherwise no symptoms. Signs: subpatellar crepitations. Full extension, 90 degrees flexion. <i>Radiography</i> , before op.: slight arthrosis deformans + osteochondritis dessicans + free body in subpatellar bursa; at follow-up examination: considerable arthrosis deformans.

TABLE III (cont.)

Case	Sex	Age at onset	Age at operation	Time of observation	Primary result of operation	Result of operation at follow-up	Comments
12. I.V.L. S 3430/39	♀	26 yrs.	27 yrs. Synovectomy (right knee)	4 yrs.	No exudate	No follow-up examina- tion	At age of 23, excision of R. medial meniscus. <i>Radiography</i> , before op.: slight diffuse decalcification.
13.* T.H. L 485/42	♂	24 yrs.	25 yrs. Synovectomy (left knee)	3 yrs.	No exudate	No exudate	Exudate in the unoperated knee about 6 mths. after synovectomy. At present no signs or symptoms in right knee. <i>Radiography</i> , before op.: and at follow-up examination: N.A.D.
14.* Hj.M. L V:C:273	♂	58 yrs.	59 yrs. Synovectomy + chondrectomy (right knee)	2 yrs.	Exudate	No exudate	Pain in knee after operation, otherwise N.A.D. <i>Radiography</i> , before op.: and at follow-up examination: arthrosis deformans.
15.* K.G.J. S 1817/38	♂	32 yrs.	36 yrs. Synovectomy (left knee)	7 yrs.	Exudate	(No exudate)	At age of 32 op. for meniscus injury, left knee. Subsequently, intermittent hydrops, first in left knee and later also in right. Only 6 yrs. after synovectomy exudate disappeared following injections of gold salts. Follow-up examination: no pain or other symptoms. <i>Radiography</i> , before op.: N.A.D.; at follow-up examination: thinning in foci of the middle part of the medial tibial condyle.

TABLE III (cont.)

Case	Sex	Age at onset	Age at operation	Time of observation	Primary result of operation	Result of operation at follow-up	Comments
16a. K.T.Ö. S 1096/37	♀	22 yrs.	29 yrs. Synovectomy + chondrectomy (left knee)	8 yrs.	No exudate	No exudate	Intermittent pain in knee joints. Otherwise no symptoms or signs. <i>Radiography</i> , before op.: very slight deformans changes.
16b. S 1096/37	♀	22 yrs.	30 yrs. Synovectomy + chondrectomy (right knee)	7 yrs.	No exudate	No exudate	
17.* R.L.S. S 5382/41	♀	30 yrs.	31 yrs. Synovectomy (left knee)	5 yrs.	No exudate	No exudate	Follow-up examination: no symptoms. Signs: considerable subpatellar erepitations. <i>Radiography</i> , before op.: slight decalcification; at follow-up examination: slight signs of arthrosis deformans.
18.* E.K.R. S 1975/41	♀	25 yrs.	35 yrs. Synovectomy (right knee)	6 yrs.	No exudate	No exudate	For a year or two after operation continuous pain in knee, and at times swelling after exertion. Follow-up examination: no symptoms. Signs: a few subpatellar erepitations, otherwise N.A.D. Large exudate in the unoperated knee. <i>Radiography</i> , before op.: very slight diffuse decalcification.

TABLE III (cont.)

Case	Sex	Age at onset	Age at operation	Time of observation	Primary result of operation	Result of operation at follow-up	Comments
18.* (cont.)							Resorption experiments with perabrodil showed considerably retarded resorption from the right knee; at follow-up, moderate arthrosis deformans
19.* A.M.D. S 3180/37	♀	20 yrs.	35 yrs. Synovectomy + chondrectomy (left knee)	10 yrs.	No exudate	No exudate	Follow-up examination: No symptoms. Subpatellar crepitations. Otherwise N.A.D. <i>Radiography</i> , before op.: moderate decalcification in patches. Slight accentuation of the joint contours; at follow-up examination: very slight deformans changes.
20.* M.H.P. S 875/43	♀	15 yrs.	25 yrs. Synovectomy (right knee)	5 yrs.	No exudate	No exudate	Follow-up examination: no symptoms. Free movement. Considerable subpatellar crepitations. <i>Radiography</i> , before op.: diffuse decalcification; at follow-up: arthrosis deformans. Recently, synovectomy of left knee. Signs of slight chondromalacia of the patella. Biopsy: synovitis dechondrodetrítica.

(No exudate) means that the exudate disappeared only a long time after the operation.

S, L and G in the first column denote whether the patient was treated at the Orthopaedic Clinic of the Karolinska Institutet in Stockholm, the Orthopaedic Clinic in Lund or at Vanförestalten in Gothenburg.

symptomless. It is well known that even a minor injury can cause severe symptoms in a joint which is the site of a pathological lesion. Such a joint is always more affected by trauma than one which is healthy. The course of a traumatic synovitis is briefly the following. After the injury hyperaemia of the synovia develops, and there is extravasation of plasma with passage of the leucocytes out of the blood vessels into the joint cavity (*Leriche* and *Policard*, *Policard*, *D. H. Kling*, *Smillie*, etc.). According to *Kling*, slight but repeated trauma can be an important factor in the development of changes in the joints. With the raised intra-articular pressure caused by the exudate, the lymphatic vessels can become obliterated (*Smillie*). The joint fluid becomes more acid, and colloids, particularly fibrin, are precipitated (*Smillie*). Secondary atrophy of the quadriceps muscle occurs, and the resulting insufficiency of the quadriceps function may increase the trauma to the joint on walking; this, in its turn, can give rise to increased exudation, etc.

Radiographic evidence of arthrosis deformans was found *at the time of synovectomy* in case 7, but in more of the other cases in which trauma was stated to be the cause of the exudate did the radiographs show any changes.

In 2 cases (Cases 8 and 9) the hydrops was intermittent. Table III shows that the condition had persisted for 6 and 2 years respectively before the synovectomy, occurring in case 8 at intervals of 6 months to 1 year, and in case 9 for 1-2 weeks at intervals of 4-6 weeks<sup>2</sup>. Two further cases, namely cases 5 and 15, may also be mentioned here.

Case 5 had intermittent hydrops for six years after a second synovectomy. When it had regressed, intermittent hydrops developed in the other, previously healthy knee. Case 15 was operated for a meniscus lesion; intermittent hydrops developed after the operation, first in the operated knee and later in the other (v. table III).

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<sup>2</sup> Several writers (*Kahlmeter*, and others) consider that the intervals should usually be closer for a definite diagnosis of intermittent hydrops. It is therefore questionable whether Case 8 should be included.

In the literature, intermittent hydrops is said to be uncommon. *Lovén* (1934) published a report of 70 cases from the literature, and added 2 of his own. *Kahlmeter*, who stressed the rarity of the condition, found 23 cases, or 2 per cent, among a large series of cases with pathological joint changes. Its aetiology is unknown. Infections, endocrine disturbances, metabolic disturbances, angioneuroses (in analogy with Quincke's oedema), allergic disturbances, arthrosis deformans, etc. have been postulated as possible aetiological factors. A variety of treatments have therefore been suggested. In addition to internal treatment and physiotherapy, x-ray treatment has been recommended. *Berger* reported a case which became entirely free from symptoms following "allergic treatment". Synovectomy has been performed in some cases. *Mandl* and *Krida* each reported 2 cases. In one of *Mandl's* cases the exudate returned after synovectomy, though at longer intervals; in the other it disappeared altogether. Both *Krida's* patients were free from exudate after operation.—Cases 8 and 9 of this paper were free from exudate after synovectomy.

In the remaining 11 cases (12 synovectomies), i.e. cases 10-20 in table III, the exudate occurred without any demonstrable cause. Of these cases, 9 became *primarily* free from exudate and 10 were free at the *follow-up examinations*.

Thus, in the hydrops group, consisting of 21 cases of synovectomy, exudate was present *primarily* after operation in 6 cases and at the *follow-up examination* in 1 case (case 10). In 4 cases<sup>10</sup>, however, its disappearance cannot be attributed to the synovectomy, since it persisted for a long time after the operation. There are thus altogether 5 cases with unrelieved hydrops out of 20 synovectomies (1 had no follow-up examination), i.e. *75 per cent were free from exudate*.

Table IV shows the radiographic findings in the entire hydrops group before synovectomy, and in those radiographed both before operation and at follow-up. It is seen that at the follow-up examination no less than 10 of the patients showed

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<sup>10</sup> Cases 1, 5, 6 and 15.



TABLE IV  
*Results of Radiographic Examination of the »Hydrops Group«  
 (21 Synovectomies; table III).*

	Before synovectomy	Follow-up radiography (14 cases)	
		Before synovectomy	After synovectomy
No radiographic changes	8 <sup>a)</sup>	6 <sup>d)</sup>	4 <sup>g)</sup>
Calcium reduction . . . .	7 <sup>b)</sup>	5 <sup>e)</sup>	—
Arthrosis deformans . . .	6 <sup>c)</sup>	3 <sup>f)</sup>	10 <sup>h)</sup>
	21	14	14

a) Cases 1, 3, 4, 5, 6, 10, 13 and 15.

b) Cases 2, 8, 9, 12, 17, 18 and 20.

c) Cases 7, 11, 14, 16 a and b, and 19.

d) Cases 1, 3, 5, 6, 13 and 15.

e) Cases 2, 9, 17, 18 and 20.

f) Cases 11, 14 and 19.

g) Cases 2, 5, 13 and 15 (in Case 15 foci of thinning of unknown origin in the tibial condyle.

h) Cases 1, 3, 6, 9, 11, 14, 17, 18, 19 and 20.

radiographic evidence of arthrosis deformans, and that in 7 of them these changes had appeared during the period between the operation and the later examination.

If the subjective results in the cases with and without arthrosis deformans are compared, it is found that out of the first group only cases 1 and 14 had symptoms, and the other 7 had no symptoms from the operated knee at the follow-up examination. Nevertheless, as has already been mentioned, cases 1 and 14 occupy to some extent a unique position, since case 1 had developed a polyarthrititis after and case 14 already had a fairly severe arthrosis deformans before operation. In case 18 the hydrops disappeared only two years after synovectomy and cannot, therefore, be included among those free from symptoms. *It can thus be stated that arthrosis deformans, which radiographically has developed after synovectomy, need not be accompanied by any symptoms.*

As regards the relation between the radiographic changes before and exudate after synovectomy only 3 of the 8 cases *without* radiographic changes before had no exudate after operation. Patients with rarefaction or with arthrosis deformans were free from exudate with one exception (Case 14). Although the number of cases in each group is small, it is impossible not to be struck by the fact that *the cases with exudate after operation were mainly from the group without pre-operative radiographic changes.*—If the late results of synovectomy are related to *the radiographic picture at the follow-up examination*, it is seen that of the 14 cases thus examined synovectomy did not have the desired result in 4, of whom 2 (Cases 1 and 6) had arthrosis deformans, 1 (Case 5) no radiographic changes and 1 (Case 15) thinning of the medial condyle of the tibia. Of the 9 remaining cases without exudate, 8 had arthrosis deformans at the follow-up examination<sup>11</sup>. In 3 of these<sup>12</sup>, the disease had already been present before operation. *It is thus evident that although radiographic signs of arthrosis deformans developed after synovectomy, no exudate occurred.*

It has already been mentioned that in a number of cases chondrectomy was performed in addition to synovectomy. This combined operation was carried out on altogether 9 patients<sup>13</sup>, or nearly half the cases in the hydrops group. All except 1 (Case 2) of the 6 synovectomy + chondrectomy cases who were radiographed at the follow-up examination had arthrosis deformans. Case 1 must nevertheless be excluded for the aforementioned reasons. It is true that in case 14 the condition was already present before synovectomy, but the changes seen on the radiographs at the follow-up showed such appreciable progression that the inclusion of the case is justified. Of the 8 cases on whom synovectomy was performed alone, who were examined radiographically at the follow-up, only 3 (Cases 9, 17 and 18) had arthrosis deformans.

<sup>11</sup> Cases 3, 9, 11, 14, 17, 18, 19 and 20.

<sup>12</sup> Cases 11, 14 and 19.

<sup>13</sup> Cases 1, 2, 3, 8, 11, 14, 16a, 16b and 19.

TABLE V

*Cases Treated by Intramuscular Drainage.*  
(All from the Orthopaedic Clinic in Lund)<sup>1</sup>.

Case	Sex	Age at onset	Age at operation	Time of observation	Primary result of operation	Result of operation at follow-up	Comments
1. L. D. 179/36	♂	43 yrs.	44 yrs. Intra-muscular drainage (right knee)	12 yrs.	Exudate	No exudate	Approx. 10 yrs. before operation the patient had transient discomfort from right knee on one or two occasions. Post-operative x-ray treatment. Follow-up examination: no discomfort from knee. Subpatellar crepitations. <i>Radiography</i> , before op.: N.A.D.; at follow-up examination: severe arthrosis deformans right knee, left N.A.D.
2. G. L. B. 135/37	♀	21 yrs.	29 yrs. Intra-muscular drainage + chondrectomy (left knee)	11 yrs.	No exudate	No exudate	Follow-up examination: no subjective symptoms. Objective symptoms: considerable subpatellar crepitations in left knee, none in right. <i>Radiography</i> , before op.: N.A.D.; at follow-up examination: N.A.D.
3. M. N. 191/37	♂	41 yrs.	41 yrs. Intra-muscular drainage + chondrectomy (right knee)	10 yrs.	Exudate	No exudate	Exudate after trauma in right knee at 38 yrs. Then free from symptoms until 41, when exudate after new trauma. Operation only 2 mths. later. Follow-up examination: subpatellar crepitations right, somewhat less left knee. <i>Radiography</i> , before op.: N.A.D.; at follow-up examination: N.A.D.

TABLE V (cont.)

Case	Sex	Age at onset	Age at operation	Time of observation	Primary result of operation	Result of operation at follow-up	Comments
4. S. M. 196/37	♀	21 yrs.	22 yrs. Intra-muscular drainage	10 yrs.	Exudate	No exudate	Exudate in connexion with trauma, also gonorrhoea. Probably a gonococcal arthritis. No fever. Follow-up examination: Knee swells on exertion. Otherwise no symptoms. No signs. <i>Radiography</i> , before op.: N.A.D.; at follow-up examination: arthrosis deformans.
5. J. J. 201/37	♂	34 yrs.	36 yrs. Intra-muscular drainage + excision of medial meniscus (left knee)	10 yrs.	No exudate	No exudate	Exudate in connexion with trauma, when the previously undiagnosed meniscus injury was also found. Follow-up examination: no symptoms or signs. <i>Radiography</i> , before op.: Some calcium atrophy; at follow-up examination: arthrosis deformans.
6. S. H. R. 232/37	♀	26 yrs.	27 yrs. Intra-muscular drainage + chondrectomy (left knee)	10 yrs.	No exudate	No exudate	Exudate without known cause. Follow-up examination: no symptoms or signs. <i>Radiography</i> , before op.: N.A.D.; at follow-up examination: slight arthrosis deformans.
7. K. O. 792/38	♂	21 yrs.	21 yrs. Intra-muscular drainage (left knee)	9 yrs.	Exudate	No exudate	Exudate without known cause. Follow-up examination: no symptoms or signs. <i>Radiography</i> , before op.: N.A.D.; at follow-up examination: N.A.D.

TABLE V (cont.)

Case	Sex	Age at onset	Age at operation	Time of observation	Primary result of operation	Result of operation at follow-up	Comments
8. R. H. 312/38	♀	41 yrs.	41 yrs. Intra-muscular drainage + chondrectomy (left knee)	9 yrs.	No exudate	No exudate	Exudate without known cause. Follow-up examination: no symptoms or signs. <i>Radiography</i> , before op.: N.A.D.; at follow-up examination: N.A.D.

<sup>1</sup> I wish to express my thanks to Docent Folke Ståhl, Lund, for his help in the clinical and radiological examinations of these patients.

Cases 9 and 18, however, also had changes in the patellar cartilage, though these were so mild that chondrectomy was not considered to be indicated. The difference in the frequency of arthrosis deformans is evident. Nevertheless, the numbers in both groups are too small to allow any comparisons to be made, particularly since only in 4 of the cases treated by synovectomy alone was it noted in the report of the operation that the patellar cartilage had been inspected. No mention was made of its condition in the remaining cases.

Actually, little is known of whether the cartilaginous changes precede or follow the exudate. The general opinion appears to be that the cartilaginous changes are primary, and the exudate secondary to them (*Läwen*, and others). Under normal conditions, suspended attrition products from the joint cartilage are present in the synovia (*Hammar*, *Meyer*, *Key*, and others). In pathological conditions there is increased attrition of the cartilage, and an increased overflow of the particles into the synovial joint. These particles are absorbed by the synovial membrane. According to *Hultén* and *Gellerstedt*, the synovial membrane then responds with hyperaemia, and increased formation of connective tissue causes thickening of the capsule (synovitis chondrodetrítica). In their opinion, the improvement after chondrectomy depends on a reduction of

the excess of attrition products and thereby removal of the cause of the synovial irritation. The present writer was, however, unable to find, in a number of cases<sup>14</sup> of severe malacic changes in the patellar cartilage, any changes in the synovial membrane like those described by *Hultén* and *Gellerstedt*. The aetiology of the irritation phenomenon in the joint need not be a synovitis chondrodetrítica in every case. On the other hand, synovitis chondrodetrítica with considerable swelling of the synovial membrane and even macroscopic oedema in the subsynovial tissue was found in one case<sup>15</sup>, in which the only cartilaginous change was a small focus of softening within the medial surfaces of the patella, without other changes in the cartilage. These observations suggest that *Hultén* and *Gellerstedt*'s explanation of the origin of the synovial irritation is not generally applicable. Although no major general conclusions can be drawn from these observations in individual cases, it nevertheless appears that the synovial reaction bears no direct relation to the degree of change in the cartilage.

There are, however, many cases of chondromalacia of the patella—and those reported here undoubtedly belong to this category—in which one is more inclined to consider the cartilaginous changes in the patella as part of a general disturbance of the normal physiology of the joint than as an otherwise isolated phenomenon. In such cases, exudate was the first clinical sign, and there is nothing to contradict the assumption that, as regards time, the exudate is actually primary to the changes in the cartilage. It is possible that the presence in a joint over a long period of a fluid which is both quantitatively, and probably even qualitatively, in respect of both its chemical composition and physical properties, pathological, can contribute to or hasten the onset of degenerative cartilaginous changes. The fact already mentioned that exudate was present mainly in those cases in which there

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<sup>14</sup> From the Orthopaedic Clinic in Lund. Case sheets 947/45, 145/46, 159/46, 252/46, 746/46, 1295/46.

<sup>15</sup> v. Case 20, Table III.

were no demonstrable changes, supports this assumption. Neither the duration of the disease up to the time of synovectomy nor the length of the period of observation, appear to affect the occurrence of arthrosis deformans. Nor is there any reason for presuming that the synovectomy per se could cause the deformans changes.

In all cases, the excised synovia was examined histologically and showed the same uniform picture as in the cases with polyarthritis, i.e. that of chronic synovitis. The results of other laboratory investigations—sedimentation rate, Wasserman reaction, tests on guinea-pigs with the exudate, etc.—were normal.

Great importance has been accorded in some quarters to the possibilities afforded by radiographic investigations of resorption. In two cases (Cases 6 and 18) from the present material attempts were made before the synovectomy to determine the rate of resorption from the knee joint. Perabrodil, a crystalline substance, was used. In case 6, where only the affected knee was examined, all contrast had disappeared from the joint after 4 hours. In case 18, both knees were studied. It was then found that after 2 hours a considerable amount of the contrast medium remained in the right, affected knee, while in the left, normal knee most of it was resorbed after 1 hour, and the rest after 2 hours. Thus there was retarded resorption in the affected knee joint as compared with the healthy one. Unfortunately, no resorption experiments were made after synovectomy.

In another case, however, which is not included in the present material, since the operation was performed fairly recently, this examination was made. The case presents some interesting aspects, and an account of it is therefore given in the following<sup>16</sup>. A 27-year old woman had a partial synovectomy in February 1947 after having exudate in the right knee continuously for 10 years. It may be of interest to note that she suffered from psoriasis. Contrast examination with pera-

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<sup>16</sup> From the Orthopaedic Clinic in Lund.

brodil before synovectomy showed considerably *more rapid* resorption from the right, affected knee than from the left. Two months after synovectomy the examination was repeated, and the rate of resorption was found to be the same in both knees. At this time there was still exudate in the right knee. Thus in this case synovectomy was followed by a reduced rate of resorption. This agrees well with the results obtained by *Efskind*, who pointed out that the resorption capacity decreases after synovectomy and even after simple arthro-tomy.

It is thus seen that of the 2 hydrops cases 1 had retarded and 1 accelerated resorption from the affected knee. In the former, (Case 18) histology showed severe fibrous thickening of the capsule wall with a plentiful formation of new vessels. In the latter, histology showed a non-specific synovitis with formation of new vessels and an infiltration of round cells round them.

The experimental studies already mentioned have shown that crystalline substances are resorbed through the blood vessels. In the two cases reported here there was plentiful new formation of vessels in the subsynovial tissue. In case 18 there was also a fibrous thickening of the capsule, which might have decreased the possibilities of resorption. The results of the investigation in the second case could be explained by the fact that the very vascular subsynovial membrane, which would facilitate resorption from the affected knee, was reduced by the operation. The synovectomy might by this reasoning be thought to have been contra-indicated in this instance. However, it must be remembered that parabrodil is a substance foreign to the organism, and the results of resorption experiments cannot answer the question whether synovectomy should or should not be performed. Further, they give no information about the absorption through the lymphatic system. Too little is yet known about the ways and means of resorption of a number of the substances composing the exudate in the knee joint.

Another operation than synovectomy has been suggested



for chronic hydrops of the knee joint, i.e. so-called intramuscular drainage (*Läven*). Table V shows that this operation was performed in 8 cases. Although they fall outside the scope of the present paper they are mentioned as they have some points of interest. It is scarcely possible to make any direct comparison between them and the patients treated by synovectomy, since the two groups differ in one or two respects. Synovectomy was only performed when the condition had lasted over five years, while the average duration in the cases treated by intramuscular drainage was only just over one year. The observation period, however, was almost twice that of the synovectomy patients, i.e. approximately 10 years. 4 of them had a primary exudate, but at the follow-up examination all were free from it. In 4 cases (Cases 1, 4, 5 and 6) arthrosis deformans was found at follow-up. *Efskind's* theory that chronic hydrops of unknown origin must be due to an increased production of joint fluid makes him regard fenestration of the capsule as an irrational operation in these cases. The cases mentioned here—which belong to the category “hydrops of unknown origin” with the reservations regarding traumatic exudate already mentioned—do not support his view.

To sum up the results of partial synovectomy: *Of 34 cases who were examined at the follow-up 21 were free from exudate, i.e. just over 60 per cent.* The results were poorer in the polyarthritis cases than in those with exudate of other origins (40 and 75 per cent respectively free from exudate). Many authors definitely warn against synovectomy in cases of polyarthritis (*Bernstein*, and others), whereas others do not regard it (*Allison*, *Boon-Itt*, *Inge*, *Massoro*, *Speed*, *Swett*, etc.) as a contra-indication.

The results reported in the present paper appear to agree with those of other writers (*Bernstein*, *Boon-Itt*, *Jones*, *Masoro*, *Speed*, *Swett*, and others). It is, however, frequently impossible to make a direct comparison between the different series. Thus, for example, the cases reported here differ from those of some other writers as regards operative technique,

the duration of observation, etc., so that the results are probably not comparable.

### SUMMARY

The writer reports 36 partial synovectomies performed on 34 patients. Fifteen of the synovectomies (14 patients) were performed on cases of chronic polyarthritis (v. table II); the exudate in the remaining cases ("hydrops group") was of uncertain or unknown origin (v. table III). Table 1 shows the duration of the disease, age at operation, etc. After operation only 6 of the polyarthritis cases and 15 of the hydrops cases were free from exudate.

In respect of patients with polyarthritis, the value of the sedimentation rate in deciding the most suitable time for the operation is discussed. It was found, however, that cases with very high sedimentation rates during the period immediately preceding synovectomy do not necessarily have poorer results than cases with a lower sedimentation rate.

The use of synovectomy in patients with polyarthritis should be limited and the cases carefully selected.

In the "hydrops group" trauma was believed to have caused the exudate in 7 cases. In 2 cases there was typical intermittent hydrops. 10 out of the 14 cases who were examined radiographically at follow-up examination showed arthrosis deformans. The development of this condition is not necessarily accompanied by any symptoms nor does it favour the onset of hydrops. The reason for the relatively large number of deformans changes is discussed.

Finally, 8 cases treated by intramuscular drainage are reported; all were free from exudate at the follow-up examination. Arthrosis deformans was present in 4 cases.

### RESUME

L'auteur rapporte 36 synovectomies partielles pratiquées sur 34 malades. Quinze de ces synovectomies (14 malades)

ont été pratiquées sur des cas de polyarthrite chronique (voir tableau II) l'exsudat des autres cas ("groupe hydropique") étant d'origine incertaine ou inconnue (voir tableau III). On voit au tableau I la durée de la maladie, l'âge des malades au moment de l'opération, etc. Après l'opération, c'est seulement dans 6 des cas polyarthritiques et 15 des cas hydropiques que l'on n'a pas trouvé d'exsudat.

Quand il s'agit de malades souffrant de polyarthrite, la valeur du taux de la sédimentation pour décider du moment le plus propice à l'opération est discutée. On a trouvé, en effet, que l'on n'obtient pas nécessairement des résultats moins favorables dans des cas ayant un taux très élevé de sédimentation durant la période précédant immédiatement la synovectomie que dans ceux ayant un taux de sédimentation plus faible.

L'usage de la synovectomie chez les malades souffrant de polyarthrite doit être limité et les cas minutieusement sélectionnés.

Dans le "groupe hydropique", on croit que ce sont des traumatismes qui ont provoqué l'exsudat dans 7 cas. Dans 2 cas il s'agissait d'hydropisie intermittente typique. 10 cas sur 14 ont été examinés à la radiographie et les examens ultérieurs ont montré des processus d'arthrosis deformans. Le développement de ceux-ci n'est pas nécessairement accompagné de symptômes et ne favorise pas l'attaque hydropique. La raison du nombre relativement élevé des modifications déformantes est discutée.

Enfin, 8 cas traités par drainage intramusculaire sont rapportés: il n'y avait d'exsudat chez aucun d'entre eux à la réexamination. On a constaté l'arthrosis deformans dans 4 cas.

#### ZUSAMMENFASSUNG

Der Verfasser berichtet über 36 partielle Synovektomien, die an 34 Patienten ausgeführt wurden. 15 der Synovektomien (14 Patienten) wurden in Fällen chronischer Polyarthrititis ausgeführt (siehe tabelle II). Das Exudat in den übrigen Fällen

(„Hydrops Gruppe“) war von ungewissem oder unbekanntem Ursprung (siehe Tabelle III). Tabelle I zeigt die Krankheitsdauer, das Alter bei der Operation, etc. Nach der Operation waren nur 6 der Polyarthritiden Fälle und 15 der „Hydrops“-Fälle frei von Exudat.

Mit Hinsicht auf die Polyarthritiden-Patienten wird der Wert der Senkungsgeschwindigkeiten zur Feststellung des günstigsten Zeitpunktes für die Operation, diskutiert. Man fand jedoch dass Fälle mit sehr hoher Senkung während der Synovektomie unmittelbar voran gehenden Periode nicht notwendigerweise schlechtere Resultate aufweisen als Fälle mit niedriger Senkung.

Die Anwendung der Synovektomie bei Patienten mit Polyarthritiden sollte eine begrenzte sein und die Fälle sollten sorgfältig ausgewählt werden.

In der „Hydrops“-Gruppe hatte ein Trauma das Exudat wahrscheinlich in 7 Fällen hervorgerufen. In zweien handelte es sich um einen typischen intermittierenden Hydrops. 10 von den 14 Fällen zeigten bei der Nachuntersuchung röntgenologisch arthrosis deformans. Die Entwicklung dieses Zustandes ist nicht notwendigerweise von Symptomen begleitet, noch begünstigt sie die Entstehung eines Hydrops. Der Grund für die relativ grosse Zahl der deformierenden Veränderungen wird besprochen.

Zuletzt werden 8 Fälle besprochen die mit intramiskulärer Drainage behandelt wurden. Alle waren frei von Exudat bei der Nachuntersuchung. Arthrosis deformans war in 4 Fällen vorhanden.

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## ON RESECTION OF THE KNEE

BY

HELGE SKARENBERG

45 cases of knee resection operated at the Coast Hospital during the years 1937-47 were studied. The patients were aged between 17 and 51 years.

*Etiology.* There were 34 cases of tuberculous osteoarthritis, and 2 with non-tuberculous conditions (one chondromalacia, one staphylococcal arthritis). In the remaining 9 cases the etiology was uncertain, but presumably it was tuberculous; 5 had other tuberculous foci (4 pulmonary, 1 had proctitis also) and one tuberculous spine. It should be mentioned that Wassermann, Gonococcal and Widal tests were performed on all the patients and were all negative in every case.

The symptomatology will not be discussed here, but the *duration of the symptoms before operation* is shown in Fig. 1.

*Other Tuberculous Manifestations.* 26 cases either had, or had had previously other manifestations of tuberculosis. In 11, pulmonary tuberculosis was confirmed by demonstration of tubercle bacilli in the sputum or stomach wash-out, the tubercle bacillus being of human type in all. 4 had previously had pleuritis. In all, 9 cases had had previous pleuritis. In addition to the primary foci, which will be discussed later, radiography showed 5 cases with healed pulmonary tuberculosis. 3 patients had tuberculosis of the spine, one with an abscess in the iliac fossa, and 2 had tuberculous osteomyelitis elsewhere. 6 had tuberculosis in other joints. 2 had genital

tuberculosis (1 epididymitis and spermatoecystitis, the other epididymitis and prostatitis), 1 renal tuberculosis and 3 tubercle bacilluria (without any other sign or symptom of urogenital tuberculosis). Of the last 6 the tubercle in the urine was of human type. Finally, one case had a tuberculous

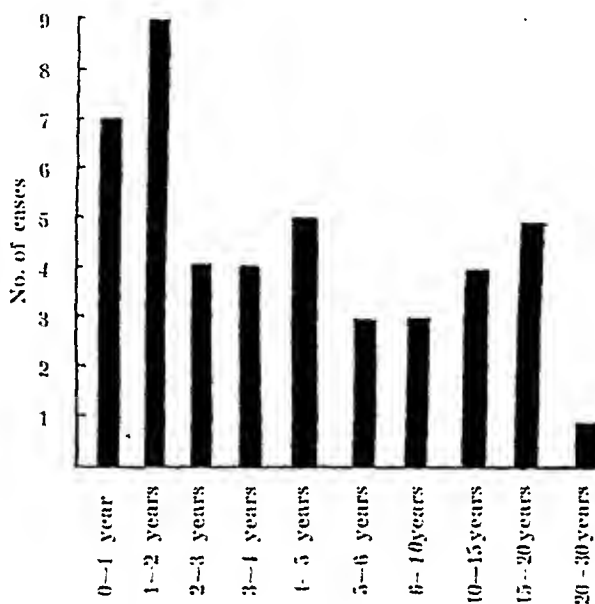


Fig. 1.

Duration of symptoms before operation.

ulcer in the retromandibular region and a tuberculoma on one leg.

*Route of Entry.* It is not possible to get a clear impression of in how many cases one could discover the route of entry, since not all cases had radiographs of the abdomen and neck. In recent years this hospital has begun to take routine radiographs of the neck and abdomen in all patients.

In this series, the route can be determined with certainty in 24, i.e. ca. 53 %. In 1, entry occurred through the tonsils; in 2, there was a double route, the tonsils and lungs, and the mesenteric glands and lungs; in the remaining 21 cases the primary focus was in the lungs.



*It is permissible to say that if this question had been investigated systematically from the beginning the figure would almost certainly be considerably higher.*

*Skin Temperatures.* In most of the cases (37) the skin temperature was determined by Ipsen's method. It was found that the skin temperature over the affected knee was from

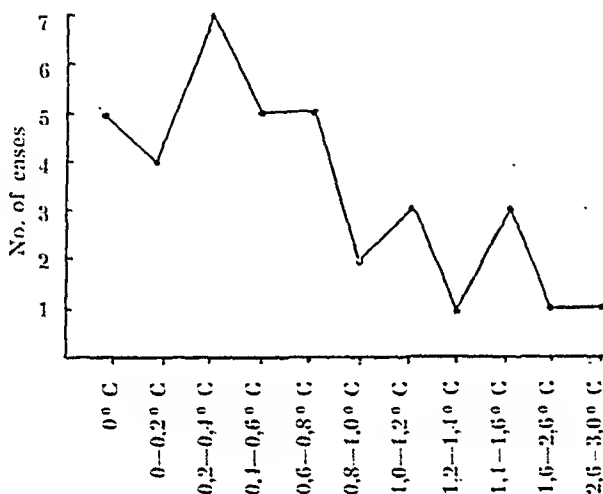


Fig. 2.

Distribution of differences of skin temperature on the 2 knees in 37 cases.

0-2.8° C higher than over the healthy knee. This is shown in Fig. 2, the abscisse representing the temperature difference, the ordinate the number of cases. The curve has a definite maximum at a temperature difference of below 1° C. Approximately the same curves were obtained for all 3 groups, viz. cases with active and inactive tuberculous osteoarthritis, cases of uncertain aetiology, and non-tuberculous cases. The last group includes, as already described, 2 cases, one chondromalacia which showed no temperature difference, and one staphylococcal arthritis with 0.9° C difference.

All groups are included in the curve in Fig. 2. Of the 5 cases which showed no temperature difference between the two sides 2 were of uncertain aetiology, 1 had inactive, 1 active tuberculosis and, as already mentioned, 1 had chondromalacia.

*Indications.* The knee was resected in all cases where it was thought that in spite of adequate conservative treatment, nearly full movement would not be recovered, since experience has shown that in these cases either relapse or a deforming arthrosis readily occurs. In practice, this means all adult patients except those with purely synovial involvement.

*Operative Technique.* In most cases the technique consisted of arthrotomy through a curved incision below the patella. The joint was widely opened, with the knee in acute flexion. After haemostasis was obtained, a curved resection of the joint surfaces was made with a saw. The raw surfaces were made to fit by means of a special curved file. All abnormal tissue was removed, and possible foci in the bone ends were curetted out. The patella was preserved in only 2 cases. A drain was only inserted if there was a sinus with mixed infection. The wound was closed with 4-5 catgut sutures in the capsule, and 7-8 fishgut sutures in the skin. 2 pins were then inserted percutaneously through the tibial tuberosity and the femoral condyles respectively, and fixed to each other by means of 2 special "stay-screws", as described by Hans Thomsen. (Ugeskrift f. Laeger, 1941, 1. 17.). Two small pieces of gauze and a little non-absorbent wool were used as dressing, and finally a plaster cast was applied from the groin to the heel. An assistant held the limb in the correct vertical position, the plaster slab was applied wet and held in position with a few circular strips. The patient was returned to bed with the limb raised about 60°.

The position was controlled radiographically immediately after the operation.

In 2 cases the operation was less radical. The inferior patellar ligament was preserved, and instead of making a curved saw-cut the cartilage was chiselled off, with, in one case the intercondylar eminence; the percutaneous pinning was also omitted.

*The Anaesthesia.* Ether anaesthesia was used in 41 cases. spinal analgesia in 4. There were no anaesthetic complications.

*The post-operative course.* There was no significant post-

operative haemorrhage. At the end of 3 weeks a window was cut in the plaster over the wound, and the percutaneous pins and the stitches were removed. 1 or 2 months later the plaster was split, and the posterior part kept as a plaster back splint. The patient was allowed up for half an hour daily when

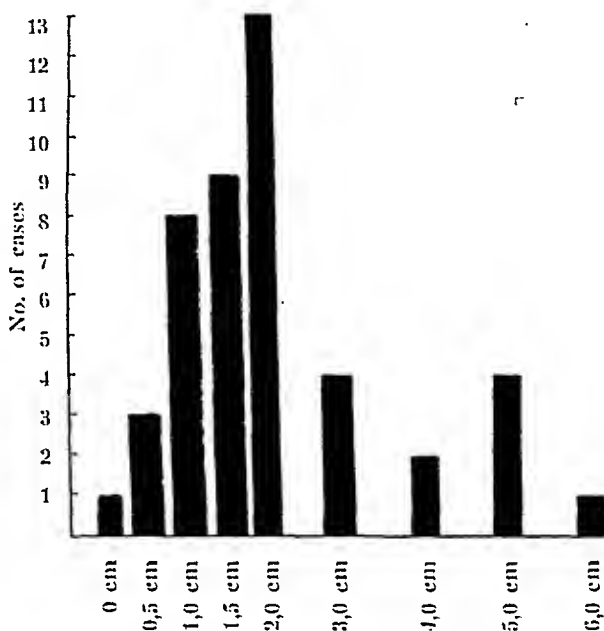


Fig. 3.

Centimetres shortening of the lower limb after re-section of the knee in 45 patients.

there was firmness at the resection site, usually after  $2\frac{1}{2}$ -3 months. A week later he was allowed to walk with crutches, beginning with 1 hour a day, and after a further month he might begin to weightbear. He was discharged without any splint, and re-examined 3 months later.

*Complications.* There were only few complications. 1 case had a peroneal paralysis which recovered in 3 months. 1 complained of slight, constant pain in the knee. He was treated with diathermy and novocain injections with some improvement. In 1 case amputation was necessary about 2 years later. She was a woman aged 35 years who still had pain

in the knee after operation; later, oedema of the leg developed and the skin became cyanotic when the leg was dependent. Finally, 2 ulcerations the size of a florin appeared on the lower 1/3 of the leg with marked discoloration of the surrounding skin. Biopsy showed mild Monckeberg arteriosclerosis. Biopsy of the sciatic nerve showed no abnormality.

*Condition.* At operation 31 of the known tuberculous cases were active and 3 were inactive.

*Position.* Nearly all cases ankylosed in good position, i.e. slight flexion and a few degrees valgus. In only 2 cases was the position not ideal. One had about 10' and the other 20' varus position at the knee.

*Shortening* amounted to 0-6 cm, with an average of 2 cm. Figure 6 shows the shortening as abscisse and the number of patients as ordinate.

*Consolidation* occurred after 1-8½ months, with an average of 2½-3 months, except for 2 cases who still had no sound union at their last examination, 1 at 3 months, and the other 5½ years after operation. These 2 patients had not, however, as will be described below, any discomfort from the knee, though slight movements were still possible.

*Working capacity.* After discharge patients were not particularly inconvenienced by the ankylosis. All could, as far as the knee was concerned, earn their own livings, except for the case already described who had pain treated by novocain injections. This patient still thought she couldn't work 7 years after the operation (functional).

### *Pathological anatomy.*

#### 1) Active tuberculous osteo-arthritis:

*Macroscopically.* Sinuses in the region of the knee were present in only 3 cases.

*Findings at operation.* Usually thickening of the capsule, erosion of the cartilage, and varying degrees of destruction of the menisci or the cruciate ligaments. Frequent pannus

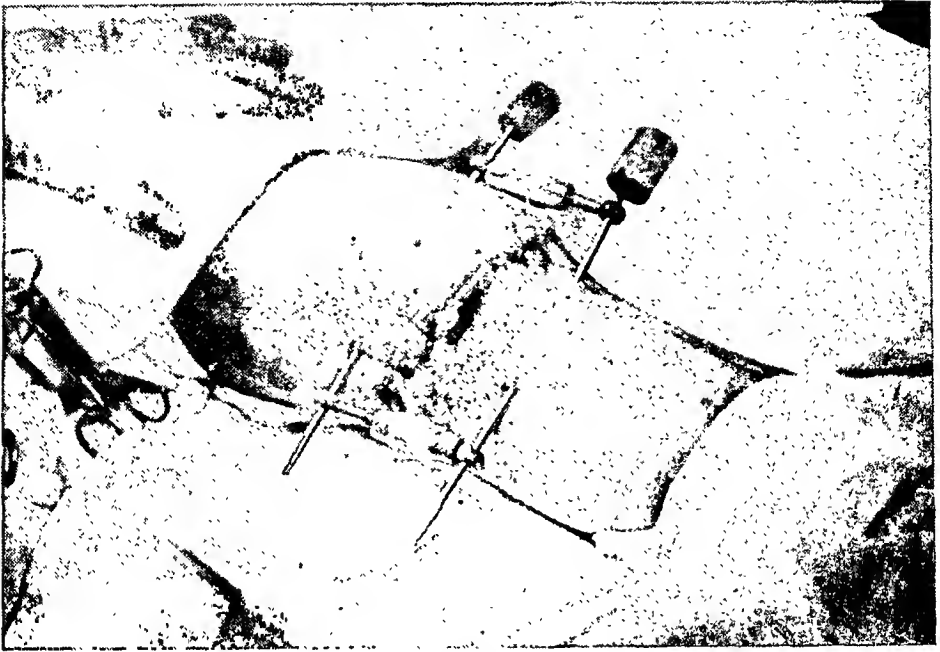


Fig. 4.

formation. The joint cavity was often obliterated by granulation tissue or fibrous adhesions. In 15 cases one or more caseous tuberculous foci were found on the sawed surface. Occasionally, there was abscess formation round the capsule. Sequestra formation was seen only in 1 case. *Histology.* The usual histological picture was seen: granulomata of epithelioid cells, containing giant cells of Langhans' type, and surrounded by lymphocyte infiltration. There was also a marked tendency to coagulation necrosis.

- 2) Inactive tuberculous osteoarthritis. The 3 cases in this group showed only fibrous adhesions; histologically nothing abnormal was found in 2, and some fibrous degeneration in 1.
- 3) Cases with Uncertain aetiology. *Macroscopically* the findings closely resembled those of the tuberculous osteoarthritis i.e. varying degrees of granulation, pannus, erosions of the cartilage and fibrous adhesions. But no tuberculous

foci and no abscesses were found. In one case the joint appeared completely normal.

On histological examination 5 of the 9 cases showed plasma cell and lymphocyte infiltration, suggesting a chronic inflammation. In 2 cases there was fibrous degeneration, and in some places ossification of the cartilage. The remaining 2 cases showed no abnormality.

- 4) Non-tuberculous cases. One was found to be a case of chondromalacia. Facing each other on the patellar and femoral surfaces were sharply demarcated areas the size of a halfpenny where the cartilage was red and velvetlike but not eroded. The consistency was soft and elastic. Histology showed both degenerative and reactive changes. The cartilage had been destroyed and replaced by cellular and vascular connective-tissue. There were also degenerative changes in the capsules of the cartilage cells.

The other case was one of staphylococcal osteoarthritis. Macroscopically no abnormality was seen. Histology showed severe degenerative changes in the cartilage. The cartilage structure showed varying degrees of change, the ground substance being fibrillary, the cells small, narrow and spindle-shaped. On the surface was a layer of loose fine-meshed connective tissue with lymphocyte infiltration. In the medulla there was proliferation of a cellular connective tissue. No evidence of tuberculosis.

*Bacteriology.* In 27 cases the tissue, pus, etc. from the knee joint were examined for tubercle bacilli. Tubercle bacilli were found in 17; 13 were of human type, and 3 bovine; the type was not determined in the remaining case. In the 3 inactive cases TB had been demonstrated previously in abscesses from the knee. In only one of these was the type determined; it was human.

3 patients had, as already mentioned, sinuses near the knee. Human type TB was found in 2, and in 1 there was also a secondary infection with staphylococcus aureus. In the third case no bacteriological examination appears to have been made.

*The post-operative radiographic appearances* after resection are illustrated by the following 2 cases whose clinical data are described in brief:

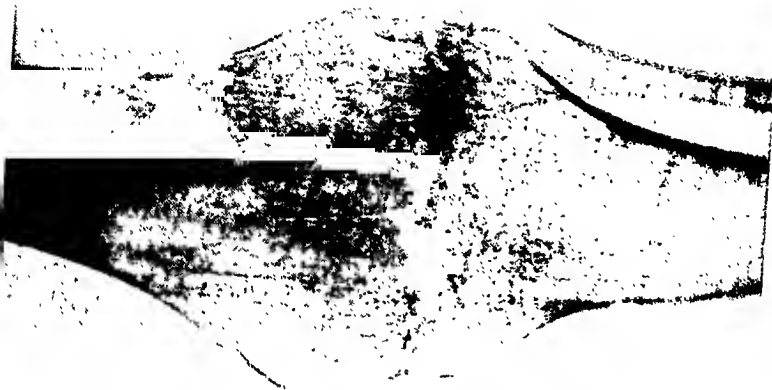
- 1) An agricultural worker aged 21 years, who had had pleural empyema 13 years earlier. The R. knee was affected when he was aged 11 years. Repeated treatment with plaster and light. Was able to work on the land for long periods, but the symptoms recurred at intervals of 1-2 years. The skin temperature was  $1.1^{\circ}$  warmer on the affected side. Very reduced movement, and the smallest movement caused pain. Obvious muscle atrophy. Slight swelling of the knee. The patella fixed. Resection performed by the usual technique under ether anaesthesia. Post-operative course uncomplicated. Microscopy showed tubercles. No tubercle bacilli seen. After 2 months, sound union in excellent position. Shortening  $1\frac{1}{2}$  cm. Excellent health at follow-up examination 7 months later. (See figs. 7, 8, 9).
- 2) A labourer aged 44 years, who in addition to the knee lesion had a bilateral tuberculous epididymitis, tuberculosis of one seminal visicle, bilateral tuberculous osteoarthritis of the carpus, osteomyelitis of the spine, tuberculous bacilluria and TB of the L. lung. Pain began in the knee when he was 38 years old; later, swelling, tenderness and restricted movement. On admission the L. knee was found to be diffusely swollen.

The patella's movement was reduced to  $\frac{1}{3}$  normal. The knee could be flexed to  $110^{\circ}$ . The tenderness corresponded with the joint line. The skin temperature was  $1.5^{\circ}$  higher than on the normal side. Resection by the usual technique. Uncomplicated post-operative course. Microscopy showed tuberculosis. The position at the joint was  $20^{\circ}$  varus and  $10^{\circ}$  flexion.

At the last follow-up examination  $5\frac{1}{2}$  years later there was still  $5^{\circ}$  movement; the position as above. He was working on the railways and stood and walked about all day, though still using a celluloid splint. (Figs. 10, 11, 12).



*Fig. 7.*  
Radiograph of Case 1 immediately  
before operation.



*Fig. 8.*  
The same case 2 months after  
operation. Beginning ankylosis.



*Fig. 9.*  
The same case 7 months after  
operation. Complete bony  
ankylosis





*Fig. 10.*

Radiograph of case 2 1 month before operation.



*Fig. 11.*

The same case 7 months after operation.



*Fig. 12.*

The same case 5½ years after operation. Pseudarthrosis at the site of excision.

## SUMMARY

45 knee resections performed at the Nationalforening's Hospital for Surgical Tuberculosis, Juelsminde are discussed.

*Etiology:*

Tuberculous .....	34 cases
Non-tuberculous .....	2 cases
Uncertain .....	9 cases

26 patients had, or had had other tuberculous lesions.

*Route of Entry* could be determined in 53 % of cases. It was not, however, systematically searched for from the beginning of the series.

*Skin temperature measurements* by Ipsen's method showed 0-2.8° rise in temperature of the skin of the affected knee; in most cases this was less than 1°.

*The indications and technique* for the operation are described.

*The following results were obtained:*

*the position* was good in all cases, except 2 which had 10-20° varus.

*the shortening* was from 0-6 cm, with an average of 2 cm.

*consolidation* occurred after an average of 2½-3 months.

*the patient's working capacity* was good in all cases, provided they had no other disabling disease.

## RESUME

45 résections du genou, pratiquées à l'Hôpital de Tuberculose chirurgicale de l'Association Nationale, à Juelsminde.

*Etiologie:*

Tuberculose .....	34 cas
non tuberculeux .....	2 cas
incertains .....	9 cas

26 des malades avaient présenté d'autres manifestations tuberculeuses.

*La porte d'entrée* a pu être déterminée dans 53 % des cas. La question n'a toutefois pas été systématiquement examinée depuis le début.

*Mensuration de la température cutanée* d'après Ipsen, a montré des variations de température de 0 à 2,8°, dans la plupart des cas 1 degré de différence.

*Indications*: tous les cas chez les malades adultes, à l'exception des formes synoviales.

Indications et technique comme indiquées, on a obtenu les résultats suivants:

*Position* bonne dans tous les cas, excepté dans 2 avec 10 à 20° varus.

*Raccourcissement* d'environ 2 cm en moyenne ( 0 à 6 cm ).

*Fermeté* au bout de 2½ à 3 mois en moyenne.

*Capacité de travail* bonne pour tous les malades, à moins qu'ils ne souffrent d'autres maladies invalidisantes.

## ZUSAMMENFASSUNG

45 Kniegelenksresektionen, ausgeführt am Nationalforenningens Hospital for kir. Tuberculose, Juelsminde.

*Ätiologi*:

Tuberkulöse .....	34 Fälle
Nicht Tuberkulöse .....	2 Fälle
Unsichere .....	9 Fälle

26 Patienten hatten oder hatten andere tuberkulöse Manifestationen gehabt.

*Die Eingangspforte* konnte man in 53 % der Fälle bestimmen. Die Frage ist jedoch nicht vom Anbeginn systematisch untersucht worden.

*Hauttemperaturmessung* nach Ipsen zeigte einen Temperaturunterschied von 0—2,8°, in den meisten Fällen unter 1 Grad unterschied.

*Indikationen:* Alle Fälle von erwachsenen Patienten mit Ausnahme der synovialen Formen.

Entsprechend der beschriebenen Indikationen und Technik findet man folgende Resultate:

*Die Stellung* ist gut in allen Fällen mit Ausnahme von zweien, die eine Varus Stellung von 10—20° zeigen. Verkürzung im Durchschnitt 2 cm (0—6 cm).

*Festigkeit* nach durchschnittlich 2½—3 Monaten.

*Arbeitsfähigkeit* gut bei allen Patienten, mit Ausnahme derer die andre invalidisierende Krankheiten hatten.



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## MORTON'S DISEASE

### *A Clinical and Patho-anatomical Study*

By

N. RINGERTZ, M.D., and L. UNANDER-SCHARIN, M.L.

#### HISTORICAL SURVEY

By Morton's disease is meant severe throbbing, burning pain and tenderness on the plantar surface of the foot, usually over the 3rd and 4th metatarsophalangeal joints, with pain radiating along the respective toes. The pain occurs when the foot is in use, e.g. when walking, and diminishes when the foot is at rest and the shoe is removed.

In 1876 *T. G. Morton*, whose name the disease bears, described the condition as "a peculiar and painful affection of the 4th metatarsophalangeal articulation". In Morton's opinion the symptoms were due to compression of branches of the external plantar nerve running to the lateral surface of the 4th toe, between the head of the 5th and the neck of the 4th metatarsals. He observed this painful condition in 12 patients, of whom 11 were women. In 3 he achieved complete freedom from pain by resecting the 4th metatarsophalangeal joint.

*Tubby* (1896), and *Tubby* and *Jones* (1898) described the disease very carefully. They classified it into three grades according to the severity of the symptoms. The most severe grade was treated by resection of the metatarsal head. In two of their operated cases the nerve was inspected, and showed

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<sup>1</sup> Read at the *Nordisk Ortopedisk Forening's* meeting in Helsingfors, June 1949.

"a well marked state of neuritis". They believed that the disease was due to pressure on a communicating nerve running between the branches of the lateral and medial plantar nerves, which run under the head of the 4th metatarsal. They also believed that the heads of the 1st and 4th metatarsals are subject to considerable pressure when the foot is in use.

Excision of the metatarsal head has also been recommended by other authors.

*Morton's disease* has been regarded by many as a condition caused by an abnormal strain on the anterior arch; they have cured the pain by non-surgical reconstruction (arch supports and orthopedic footwear). (*Pollosson* (1889), *Woodruff* (1890), *Bradford* (1891), *Guthrie* (1892), *Gibney* (1894), *Bose* (1894), *Goldthwait* (1894), *Lamacq* (1896), *Hohman* (1948) and others).

At one time it was supposed to be caused by inflammatory changes in the metatarsophalangeal joint, bursae or ligaments. (*Frank* (1904), *Hertzler* (1926), *D. J. Morton* (1935) and others).

In 1893, *Hoadly* gave a detailed account of 6 cases of metatarsalgia. In one of these, which had not responded to conservative treatment, he exposed the digital branches of the lateral plantar nerve of the 4th toe and found a small neuroma. He resected the nerve. A prompt and complete cure was obtained.

*Hoadly's* observations do not seem to have aroused great interest amongst his contemporaries, however, for it was not until 40 years later, in 1935, that resection of the nerve was again advised as a treatment for *Morton's disease*. *Sir Harold Stiles*, the English surgeon, was operated on for long-standing metatarsalgia. The nerve between the 3rd and 4th toes was resected.

After *Betts's* investigation (1940), resection of the nerve became the generally accepted procedure. He was the first to make a histological examination of the resected nerves; he examined nerves from 10 cases. *Betts* interprets the disease in the following way. "The fourth nerve is formed by the internal plantar, with a communicating branch from the external

plantar, each coming round from opposite sides of the belly of the flexor brevis and crossing obliquely before they unite. Two to three centimetres distally the nerve divides, to pass to the adjacent sides of the 3rd and 4th toes. The nerve lies immediately on the transverse ligament, which is a very firm structure". When the foot is in action, the flexor brevis contracts and the nerve is stretched. The thickening of the nerve is due to chronic irritation. Histologically, *Betts* found "a great increase in the fibrous tissue elements of the nerve".

In 1943, *McElvenny* made a histological examination of five of twelve resected nerve specimens and said that "they appeared to be either neurofibromata or angio-neurofibromata".

*Baker* and *Kuhn* (1944) abolished the pain in 14 cases by resection of the nerve. The histological picture was said to resemble that of an amputation neuroma.

*King* (1946) made a histological examination in five cases. He suggested the term "sclerosing neuroma" and drew an analogy with keloid. He attributed the condition to chronic trauma.

*Bickel* and *Dockerty* (1947) operated on 18 cases, and gave a detailed patho-anatomical report. They found oedema, fibrosis, demyelination and cyst formation in the nerves, and endarteritis in the vessels. Further they found a correlation between the length of the history and the severity of the changes. They say, "There is considerable evidence that trauma from weight-bearing in small or otherwise ill-fitting shoes is responsible for the pathogenesis of the lesion".

*Nissen* (1948) examined 27 cases. He rejected chronic trauma of the interdigital nerve as the cause. He believed that "the primary lesion is one of local vascular degeneration leading to a variety of changes in and around the cutaneous nerve. An ischaemic lesion".



## THE AUTHORS' MATERIAL

*A. Clinical Data.*

The material comprised 17 patients, 13 women and 4 men. In 16 the condition was unilateral, and in 1, which in this series has been counted as two cases, bilateral, thus giving 18 cases in all. In all cases the interdigital nerve was resected and examined patho-anatomically.

*The patient's age at the time of operation* is shown in tables 1 and 2: 12 patients, i.e. two-thirds of the material, were aged between 30 and 42 years. The remaining 6 cases were between 42 and 58 years. The youngest patient was aged 30 years.

TABLE 1  
*Cases of Morton's Disease.*

Sex	Age	Past history	Fibrosis	Endarteritis
F	34	36 months	0	0
F	34	24 "	(+)	
F	58	48 "	+	
F	52	456 "	+	
M	54	12 "	+	
F	52	7 "	+	+++
M	40	84 "	+	
F	36	12 "	+	(+)
F	57	60 "	++	+++
F	42	120 "	++	
F	37	36 "	++	+++
F	36	4 "	++	+++
F	31	60 "	++	++
F	46	36 "	+++	+
M	36	3 "	+++	+++
M	36	120 "	+++	+++
F	30	12 "	+++	+++
F	42	96 "	++++	

*Length of history* (see table 1). Only 3 patients had had symptoms for less than 1 year. 8 patients had had symptoms from 1 to 4 years; 6 for over 5 years. The longest history was found in a patient aged 58 years, who had had symptoms for 38 years.

*Occupation.* 10 of the female patients were housewives, 1 was a laundress and 2 did no work at all. 2 of the men were factory hands, 1 was in the fire brigade and 1 was a teacher.

1 patient attributed the condition to a distortion of the foot, which had been treated for two months in plaster-of-paris, and 1 to a fracture of the 5th metatarsal which had also been treated for two months in plaster-of-paris. In both cases the symptoms developed as soon as the plaster-of-paris was removed. 2 patients attributed the condition to advanced pregnancy.

*Symptoms.* 14 patients complained of aching and burning pain between the 3rd and 4th toes: 2 of similar pain between the 2nd and 3rd toes: and 2 of pain between the 4th and 5th toes. The pain always radiated to the adjacent toes, and, in two cases also up the leg. Several patients complained of numbness and a feeling of cramp in the affected toes. Usually the patients described the sensation as like stepping onto something sharp. The pain always began when the foot came into action and increased in intensity the more the patient walked. Intermittence of the pain was also reported. Many patients were at times unable to go out of doors. The pain disappeared almost instantaneously if the shoes were removed and the foot placed at rest. Walking either barefoot or in slippers was less painful than walking in hard shoes. The complaint was constant and severe, and the patients were seriously inconvenienced.

*Objective findings.* In two-thirds of the cases the shape of the foot was normal, whereas in the other third the anterior arch was moderately depressed but not contracted. In one case, where the anterior arch was of a transverso-plane type, there was a subluxation at the 4th metatarsophalangeal joint. The skin appeared normal and there were no external sign of circulatory disturbance. The patients stated that they often had severe tenderness in the aching interspace, that it was recurrent and was accompanied by radiating pains or numbness in the adjacent toes: there seemed to be tenderness in the region of the neighbouring metatarsophalangeal articulation.

though it is difficult to demarcate this tenderness very distinctly. In one case there was slight swelling on the dorsal aspect of the affected interspace. Sensory tests were made in some cases, but they revealed nothing abnormal.

*Previous treatment.* Usually the patients expect relief from an arch support; they visit shops specialising in such appliances and buy arch supports of various types. When these have proved ineffective they seek medical advice. Cases, in our series, in whom the correct diagnosis had not been made, had been classified as e.g. Buerger's disease, polyarthritis, sciatica, arthrosis of the metatarsophalangeal articulation, etc., and treated in accordance with these diagnoses.

*Treatment.* After conservative treatment, which in no case had any effect, had been tried, the interdigital nerve at the site of the pain was resected. In 14 cases this was the 3rd, in 2 the 2nd, and in 2 the 4th interdigital nerve. A longitudinal incision was made on the plantar aspect of the foot corresponding to the anterior arch. From 1-2 cm. of the nerve corresponding to the bifurcation was resected. Macroscopically the nerves appeared to be thickened to the size of a slate pencil, or in some cases to the size of a pea, whilst in others there was no appreciable thickening.

*Follow-up examinations* were made in all cases. The period of observation varied from 3 months to 4 years, most were examined between 1 and 2 years after operation.

The results were as follows:

Subjectively completely cured .....	14 (77.8 %)
Subjectively improved .....	3 (16.7 %)
Subjectively unchanged .....	1 ( 5.5 %)

The recalcitrant case was the one already mentioned (see page 4), with a painful luxation in the metatarsophalangeal joint of the 4th toe, in addition to the Morton's disease. In this case, however, the radiating pain in the toes disappeared after the operation, and the character of the remaining symptoms indicated that they were due to the untreated luxation.

At the follow-up examination, the site of operation and the

whole front part of the foot were carefully inspected and palpated, and a sensory test was made on the toes. Previous authors have been afraid that the operation scar on the sole of the foot might inconvenience the patient. Our experience in this material shows, however, that in the majority of the cases the scar was barely noticeable or palpable. In one half of the material, consisting of those observed for the longest time, no definite sensory disturbance could be detected, whereas in the other half there was sensory impairment, which the patients had usually not noticed. No swelling suggesting an amputation neuroma was observed.

When diagnosing Morton's disease, it is necessary to exclude cases with the usual types of anterior arch trouble. In these cases the complaints are located more diffusely in the whole of the anterior arch; there is no radiating pain in the toes; and the pain often persists after the foot has been put to rest. We have called this pain metatarsalgia. Cases with metatarsalgia usually have a contracted, depressed, anterior arch with tender corns under the medial metatarsal heads.

The favourable results of resection of the nerve in Morton's disease encouraged us to try the operation in cases of metatarsalgia which had proved difficult to treat. The nerve was resected in 5 cases of metatarsalgia; all were followed up, and the result was unsatisfactory in all.

In order to show the relative frequency of these cases of metatarsalgia and of cases of Morton's disease, the number of cases registered at the Orthopedic Clinic of the Karolinska Institutet during the years 1945—47 under the diagnosis "pes transversoplanus" and Morton's disease are shown:

Pes transversoplanus .....	740 cases
Morton's disease .....	32 cases

Cases of transversoplanus were more than twenty times as frequent as cases of Morton's disease. During this period 8 of the 32 cases of Morton's disease were operated on. 6 of them were examined patho-anatomically and are included in this material.

### *B. Patho-anatomical examination.*

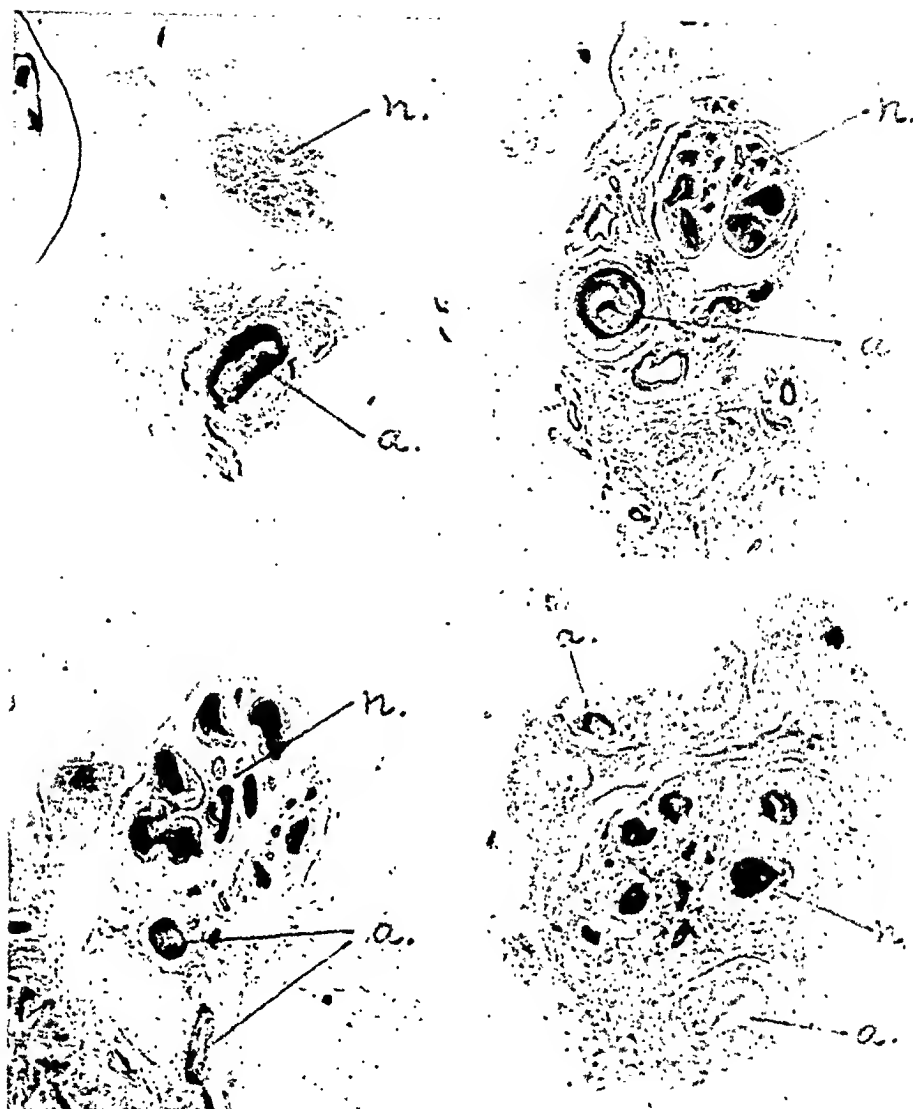
The patho-anatomical changes in the nerves excised from our 18 cases of Morton's disease can be divided into four main groups (1) fibrosis, (2) endoneural oedema, (3) demyelination of the nerve and (4) vascular changes.

(1) *Fibrosis*. This is very variable in degree. In some cases there was macroscopic swelling of the nerve, limited to the part lying between the capsules of the metatarsophalangeal articulations. In some cases the swelling was as large as a pea or bean, and in these the hypertrophied nerve was more or less adherent to the adjacent structures. In other cases the nerve was not appreciably swollen. Microscopically the fibrosis was found to be perineural. In the mild cases there was merely slight thickening and condensation of the perineural capsule, and the nerve bundles were only slightly separated; the nerve was separated from the neighbouring arteries, synovial sheaths and joint capsules by loose interstitial tissue or adipose tissue. In cases where the fibrosis was more marked, the nerve bundles were separated by a compact mass of connective tissue, which also bound the nerve to the surrounding structures and embedded the larger trunks of the interdigital arteries. In some cases the connective tissue mass enclosed small bursal cavities, probably derived from the neighbouring synovial sheaths.

Endoneural fibrosis was seen, but was not particularly marked. No proliferation of Schwann's cells, nor infiltration with inflammatory cells, either endoneural or perineural, was seen in any of the cases.

In order to be able to demonstrate the variable degree of fibrosis, we have graded the changes +, ++ and +++, as in figure 1 a. These degrees of fibrosis were found in all but one case, in which the nerve was converted into a bean-sized fibrous nodule (figure 1 b).

(2) *Endoneural oedema*. In a number of cases there was oedema within the nerve bundles segregating the nerve fibres (fig. 2). This varies considerably in degree, both from case to case and in the different bundles of the same nerve. We have



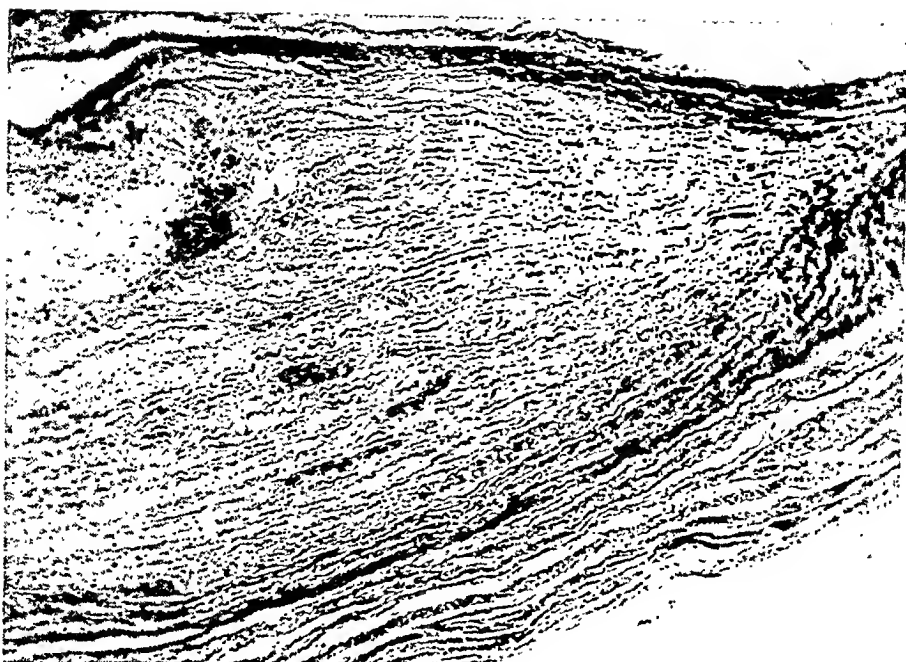
*Fig. 1a.*

Varying degree of perineural fibrosis. Cross sections of interdigital neurovascular trunks (Smith-Quinley stain). Myelinated nerve bundles and most of the vessels stain rather deeply black, connective tissue a paler shade. Upper left picture shows a specimen in apparently normal condition, nerve (n) free from the interdigital artery (a). The other pictures show fibrosis designated + to +++. The nerves are fused on to the vessels by connective tissue, which also separates the nerve bundles (Magnified about 12 ×).



*Fig. 1b.*

The greatest degree of fibrosis found in the present series. Longitudinal section of one-half of a bean-sized nodule, with the nerve entering on the left. The nerve bundles are partly demyelinated and widely separated by dense connective tissue. This degree of fibrosis is designated ++++ (Smith-Quinley myelin stain, same magnification as figure 1a).



*Fig. 2.*

Endoneurial oedema Oblique longitudinal section of nerve bundle with moderate perineurial fibrosis. (Mallory stain).

not encountered any oedema in the perineurial connective tissue.

(3) *Demyelination.* We have demonstrated this phenomenon by Smith-Quinley staining of paraffin-embedded sections. It appeared as a more or less marked loss of staining of the myelin sheaths. Unfortunately the material did not permit an exhaustive examination with frozen sections and fat stains. No signs of early myelin decomposition were found. Demyelination varies considerably from case to case and within bundles of the same nerve. There was a certain degree of parallelism between the intraneurial oedema and demyelination, but it was not constant. No parallelism was found between the degree of fibrosis and the demyelination.

(4) *Arterial changes.* These were found mainly in the larger arteries, the interdigital trunks and their larger branches down to a diameter of about  $75\ \mu$ ; they consisted in pro-





*Fig. 3.*

Various degrees of endarteritis. Upper left picture shows slight change, designated +, it consists mainly in hyperplasia of the internal elastic membrane. The upper right picture shows more advanced changes with an intimal cushion rich in elastic tissue (++). The two lower pictures show severe endarteritis (+++), the right one with an obstructive connective-tissue plug and small recanalisation lumina.

(Elastin-v. Gieson stain).

liferation of the subintimal layer and its elastic structures. If the change was slight, there was a hyperplasia of the tunica elastica with multiplicity of its lamellae; if more advanced, there was formation of connective-tissue cushions, very rich in elastic tissue, so that the lumen became irregularly constricted and split-shaped. In some cases the remaining lumen was filled with a fibrous mass less rich in elastic tissue; in this mass were endothelium-covered lumina resembling recanalization lumina in thromboses. Recent thromboses were, however, never seen. The arterial changes varied in different sections of the same specimen. The smaller arteries, especially the intraneural, were usually unchanged, and an insignificant change was found in the subintimal layer of such vessels in only a few cases. Neither intimal changes of an atheromatous type nor any calcification were found in the material. No changes were found in the media. In the cases with marked perineural fibrosis, where the arteries were embedded in the connective tissue, the tunica adventitia was condensed; otherwise its appearance was normal. Inflammatory infiltration of the artery was never encountered. Figure 3 shows the different grades of arterial change, +, ++ and +++.

The veins showed in many cases mild changes consisting of superficial intimal cushions rich in elastic fibres.

All these changes varied considerably. In many cases there was no visible fibrosis, and in others it was only slight. In about one half of the cases, however, it was well marked and even in some cases severe. It is difficult to estimate the frequency of arterial changes because, as we have pointed out, the changes can usually only be found in the larger arteries, and, unfortunately, these have been seen in the biopsy specimens of only 11 out of 18 cases. In most of them however, the larger arteries did show changes.

*Bickel* and *Dockerty* state that the degree of pathological change is proportional to the length of the history. This, however, was not true of our material. Table 1 shows the cases arranged in order of the severity of the fibrosis. It will be seen that there are cases with a very long history and only a slight

fibrosis, and vice versa. On the other hand there is some parallelism between the arterial changes and severe fibrosis.

In order to ascertain how far these observed changes are characteristic for subjects with the clinical picture of Morton's disease, we examined the interdigital nerves and arteries in a series of post-mortem cases of more or less the same age as these cases of Morton's disease. The bodies were those of healthy subjects who had died suddenly from various causes (material from the Department of Forensic Medicine), and of hospital patients who had died from various diseases, e.g. tuberculosis in quite a number of cases, surgical conditions, blood diseases, acute infections, etc. Cases of arterio-sclerosis or other cardiovascular disorders were excluded. As far as it was possible to ascertain from the hospital records and other information, none of them had ever had any foot disease of the Morton type. In each case the interdigital nerves, together with the surrounding connective tissue and arteries, especially from the parts where the nerves pass between the metatarsophalangeal articulations, were dissected out of the left foot. Three or four arterial nerve trunks were examined in each case, and the examination always included the trunk between the 3rd and 4th toe. At microscopy, special attention was paid to the four changes mentioned above, i.e. fibrosis, endarteritis, endoneural oedema and demyelination. Fibrosis and endarteritis were graded as for Morton's disease. Table 2 shows 18 Morton's and 22 control cases, arranged according to age. The control cases were classed with the severest grade of change found in any of the excised neurovascular trunks. The trunks most affected were usually those between the 2nd and 3rd and the 3rd and 4th toes.

Table 2 shows a high incidence of both fibrosis and endarteritis in the control material. Admittedly, the fibrosis was never so marked as in the few Morton cases with the most marked changes, but nevertheless it is comparable with that seen in most of the cases. The arterial changes were equally marked, both as regards type and degree of severity in the control material, and in individual cases they were even more

TABLE 2

Sex	Age	Fibrosis	Oedema	Denyelination	Endarthritis	Sex	Age	Fibrosis	Oedema	Denyelination	Endarthritis
<i>Cases of Morton's Disease.</i>						<i>Controls.</i>					
F	58	+	0	+		M	63	+	0	0	+
F	57	+	+	+	+	M	51	+	0	0	+
M	54	+	+	+		F	50	+	0	0	+
F	52	+	+	+		F	50	(+)	0	0	+
F	52	+	+	+	+	F	48	+	0	+	+
F	46	+	+	+	+	F	45	+	0	0	+
F	42	+	+	+		F	44	+	+	0	+
F	42	+	+	+		M	42	+	(+)	0	+
M	40	+	+	+		M	42	+	0	0	+
F	37	+	0	+	+	F	42	+	0	0	+
M	36	+	+	+	+	F	39	+	+	+	+
F	36	+	0	0	(+)	M	37	+	0	0	+
M	36	+	+	+	+	F	35	+	+	+	0
F	36	+	+	+	+	F	32	(+)	0	0	+
F	34	+	0	+	+	F	31	(+)	0	0	(+)
F	34	0	0	0	0	F	30	+	+	0	+
F	31	+	+	0	+	M	30	0	0	0	(+)
F	30	+	0	+	+	M	29	+	(+)	+	+
						M	28	+	0	0	(+)
						M	19	+	0	0	+
						M	16	0	0	0	(+)

severe than in any of the Morton's cases. In the control material the endarteritis was more constant in cases aged over 40 years, although it occurred also in one or two below 40. The endoneural oedema and the demyelination were much less frequent in the control material, occurring only occasionally. In table 3 the frequency of the different phenomena in the controls and in Morton's cases are compared. It will be seen that the frequency of arterial changes was so similar that the difference is negligible. There was also a similarity in the frequency of fibrosis but, as we have pointed out, in some cases of Morton's disease the fibrosis was much more severe than in the control material. Intranural oedema and demyelination, however, were definitely more common with Morton's disease cases than in the control material, and even the degree of these changes (not shown in Table 2) was more marked with Morton's disease.

TABLE 3

		Cases of Morton's Disease	Controls
Fibrosis	≡++	10/18 = 55.5 %	11/21 = 52.4 %
Endarteritis	≡++	8/11 = 72.7 %	13/21 = 61.9 %
Oedema . . . . .		11/18 = 61.1 %	5/21 = 23.8 %
Demyelination . . . .		15/18 = 83.3 %	4/21 = 19.0 %

TABLE 4  
*Metatarsalgia.*

Sex	Age	Fibrosis	Oedema	Demyelin- ation	Endarteritis
F	46	+	0	0	+
F	41	+	0	0	+++
F	36	+	+	0	+++
F	33	+	0	0	++
F	18	0	0	0	0

As supplement to these control examinations, excised digital nerves taken from five patients suffering from metatarsalgia (see page 7.), were examined. Table 4 shows the changes present in this small material. It will be noticed that

in these cases there were also considerable arterial changes, but fibrosis and the other phenomena were practically absent.

## DISCUSSION

In the literature there have been two schools of thought on the pathogenesis of Morton's disease. One, to which, among others, *Morton, Tubby and Jones, Bickel and Dockerty, Betts* and *McElvenny* belong, believes that the condition is caused by chronic trauma to the interdigital nerve, brought about by pressure or crushing. The other, led by *Nissen* believes that it is primarily an endarteritis in the interdigital artery which leads secondarily to ischemic changes in the nerve.

Our patho-anatomical examinations have shown that chronic endarteritis is a frequent phenomenon in Morton's disease. At the same time, examination of a control material showed that endarteritis of this type occurs with approximately the same frequency and the same degree of severity in persons who have no disease of the feet. It is quite possible that endarteritis in the interdigital arteries causes fibrosis of the nerves, but this process seems to be so common in this region of the body that one asks oneself whether, after a certain age, it is not physiological. In most cases it does not give rise to any painful symptoms. Further, there is no evident relation in our material between these phenomena and the duration and severity of the symptoms. One must, therefore, presume that the pain in the Morton's cases is caused by one or more additional factors—these factors being either quite independent of the endarteritis-fibrosis complex or in direct conjunction with it. The fact that Morton's symptoms subside after excision of the nerve does not necessarily mean that the cause of the pain is a change in the nerve itself. It could mean merely that excision of the pain track abolishes the symptoms. It is interesting to find, however, that the most usual age for the onset of Morton's disease coincides with the time when, to judge from the control material, interdigital arteritis also

begins to be common. It is also worth while pointing out that intraneural oedema and demyelination seem to be more common in the Morton's cases than in the control cases. This might indicate that the pain is in some way connected with some specially accentuated disturbance of the circulation or metabolism of the nerves in these cases.

Apart from the problem which particularly interests us in this investigation, viz. the pathology of Morton's disease, we find the frequent occurrence of endarteritis in this region of the body of very great interest. Our small material is, of course, only sufficient to indicate the approximate frequency of the phenomenon and the general type of the changes. It may be said that the changes have certain characteristics in common with Bürger's endarteritis obliterans, but rapid thrombosis and inflammatory infiltration, which are both part of the classical Bürger picture, are not seen. A ready suggestion is that the arterial changes in question are closely allied to the strain placed upon the foot. In order to gain support for this theory, it would be necessary to carry out a more comprehensive investigation on autopsy material, with a view to estimating still more closely the frequency of the changes at various ages and their sites, and to comparing the findings with those in the interdigital neurovascular trunks of the hand, etc.

#### SUMMARY

The clinical picture, treatment, results of treatment and the patho-anatomy in 18 cases of Morton's disease are surveyed. Morton's disease has a typical clinical picture distinct from other painful conditions in the anterior part of the foot. It is characterised by: pain when the foot is in use, tenderness, usually felt between the metatarsophalangeal articulations of the 3rd and 4th toes, and radiating pain, often with cramp and numbness, in the adjacent toes. The pain disappears immediately the foot is placed at rest. Resection of the interdigital nerve gives complete freedom from pain and does not

seem to cause any complications in the form of amputation neuromata or cicatricial tissue.

The patho-anatomical examination showed that four main changes are found in the nerve: perineural fibrosis, endarteritis in the interdigital arteries, endoneural oedema and demyelination of the nerves.

Examination of the interdigital neurovascular trunks in the feet of a control material of autopsy cases, who had not had any symptoms of Morton's disease, showed that perineural fibrosis and endarteritis occurred with the same frequency as in the Morton's cases, but that intraneural oedema and demyelination were considerably less frequent in the control material. Fibrosis was not so marked in the control material as in some of the cases of Morton's disease. There was, however, no parallelism between the degree of fibrosis and either the duration or the severity of the Morton's symptoms.

The theory expounded by Nissen, that Morton's disease depends on a primary endarteritis and a secondary fibrosis as a consequence of circulatory disturbances, cannot be said to give a full explanation. Our control examinations showed that after the age of 40 years the endarteritis-fibrosis complex is so common in the interdigital neurovascular trunks of the foot, that one wonders whether it may not after all be physiological (weight bearing?); Morton's disease on the other hand is comparatively rare. Some special factors, so far unknown, and possibly connected with endarteritis or fibrosis, must be presumed for the appearance of the pain complex. It is possible that the high incidence of intraneural oedema and demyelination characteristic of the Morton cases may provide a clue for further investigations into the true pathogenesis of the disease.

#### RESUME

Description du tableau clinique, du traitement, des résultats thérapeutiques et de l'anatomie pathologique de 18 cas de la maladie de Morton.

La maladie de Morton a un tableau clinique typique, distinct de toute autre affection de la partie antérieure du pied.



Il se caractérise par les symptômes suivants: douleur à la marche, sensibilité douloureuse généralement ressentie entre les articulations métatarso-phalangiennes des 3ème et 4ème orteils, et douleur irradiante souvent accompagnée de crampes et d'engourdissement dans les orteils adjacents. La douleur disparaît dès que le pied est mis au repos. La résection du nerf interdigital supprime immédiatement toute douleur et ne semble par donner lieu à des complications sous forme de névrome d'amputation ni d'hyperplasie fibreuse.

L'examen anatomo-pathologique décèle quatre modifications principales du nerf : fibrose périneurale, endartérite des artères interdigitaux, oedème endoneural et démyélinisation des nerfs.

L'examen des nerfs et vaisseaux interdigitaux du pied sur un matériel de contrôle constitué par des cas d'autopsie de sujets n'ayant présenté aucun des symptômes de la maladie de Morton prouva que l'on rencontre la fibrose périneurale et l'endartérite aussi fréquemment que dans les cas de la maladie de Morton. Par contre, les cas d'oedème intraneural et de démyélinisation sont beaucoup moins fréquents dans le matériel de contrôle. La fibrose n'est pas aussi marquée dans le matériel de contrôle que dans certains des cas de la maladie de Morton. Il n'y a cependant aucun parallélisme entre le degré de la fibrose, la durée ou la gravité des symptômes de la maladie de Morton.

La théorie exposée par Nissen, suivant laquelle la maladie de Morton est due à une endartérite primaire et à une fibrose secondaire, conséquences de troubles circulatoires, ne paraît pas donner une explication entièrement satisfaisante. Nos examens de contrôle montrent qu'au-delà de 40 ans le complexe endartérite-fibrose est si commun dans les nerfs et vaisseaux interdigitaux qu'on se demande si, après tout, ce n'est pas un phénomène physiologique ( poids à porter ). La maladie de Morton est par ailleurs relativement rare. Un ou plusieurs facteurs particuliers, inconnus jusqu'à présent, se rattachant à l'endartérite ou à la fibrose, suscitent peut-être le complexe douloureux. Il est possible que la forte incidence de l'oedème intraneural et de la démyélinisation qui caractérisent les

cas de la maladie de Morton puissent guider les recherches tendant à établir la véritable pathogénèse de la maladie.

### ZUSAMMENFASSUNG

Das klinische Bild, die Behandlung, die Behandlungsergebnisse und die pathologische Anatomie in 18 Fällen von Mortons Krankheit werden zusammengestellt und besprochen. Mortons Krankheit zeigt ein typisches klinisches Krankheitsbild, das sich von anderen schmerzhaften Zuständen im Vorfusse deutlich unterscheidet. Es ist charakterisiert durch Schmerzen, die beim Gebrauche des Fusses auftreten, und durch Schmerzhaftigkeit, die gewöhnlich zwischen den Metatarsophalangeal-Gelenken der 3. und 4. Zehen gefühlt wird, ferner durch ausstrahlende Schmerzen, oft verbunden mit Krämpfen und Parästhesien, in den erwähnten Zehen. Der Schmerz verschwindet, sobald der Fuss ruhig gehalten wird. Resektion des Interdigitalnerven führt zur vollständigen Befreiung vom Schmerz und scheint keinerlei Komplikationen in Form von Amputationsneuromen oder Narbengewebe hervorzurufen.

Die pathologisch anatomische Untersuchung erwies, dass hauptsächlich viererlei Veränderungen am Nerven vorgefunden werden: Perineurale Fibrose, Endarteriitis der Interdigitalarterien, endoneurales Ödem und Markscheidenverlust des Nerven.

Untersuchungen des interdigitalen neurovaskulären Bündels an den Füßen eines Kontrollmaterials von Autopsiefällen, die keinerlei Symptome von Mortons Krankheit hatten, zeigten, dass perineurale Fibrose und Endarteriitis ebenso oft zu beobachten waren, als in Fällen von Mortonscher Krankheit, dass aber das intraneurale Ödem und der Markscheidenverlust bedeutend seltener im Kontrollmaterial zu sehen waren. Fibrose war nicht so ausgeprägt im Kontrollmaterial wie in einigen Fällen vor Mortons Krankheit. Man konnte jedoch keinen Parallelismus zwischen dem Grade der Fibrose und der Dauer und Schwere der Krankheitssymptome feststellen.

Nissens Theorie, dass Mortons Krankheit von einer primären Endarteriitis ausgeht, die eine sekundäre Fibrose auf Grund der Zirkulationsstörungen zur Folge hat, kann nicht

als eine voll zureichende Erklärung angesehen werden. Unsere Kontrolluntersuchungen zeigten, dass sich nach dem vierzigsten Lebensjahre der Endarteriitis-Fibrose Komplex in den interdigitalen neurovaskulären Bündeln so allgemein nachweisen lässt, dass man sich fragt, ob es sich hier nicht um physiologische Veränderungen (Belastung?) handelt. Mortons Krankheit ist immerhin eine seltene Erscheinung. Irgendein besonderer Faktor, vorläufig unbekannt und möglicherweise mit der Endarteriitis und Fibrose verbunden, muss als Ursache für das Entstehen der Schmerzen angenommen werden. Möglicherweise kann das häufige Vorkommen von intraneuralem Ödem und Markscheidenverlust, so charakteristisch für Mortons Krankheit, einen Hinweis für die weitere Untersuchung der wirklichen Pathogenese der Erkrankung geben.

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ON INJURIES TO  
THE ACROMIO-CLAVICULAR JOINT

*Treatment and Results.*

BY

ERIK MILLBOURN, M.D.

There are several important works on injuries to the acromio-clavicular joint. Outstanding are those by *Usadel* (1941), describing 105 cases from the Heidelberg Clinic, and *Urist* (1946), giving accounts of 41 cases, from an American military hospital stationed partly in Germany and partly in England, which were personally treated by him. *Usadel* points out that these injuries increased in frequency after the 1914-18 war, in relation to the higher speed of traffic. *Urist* finds that they were common during the world war 1939-45, for various reasons. *Lord* and *Coutts* describe them as a typical injury at the American parachutist school.

During the years 1937-46, 57 cases sufficiently severe to need radiography have been treated either as out-patients or in-patients at Lund Surgical Clinic. There was a fairly even distribution of 7-10 cases a year, with the exception of the years 1941-42 and 1944-45, when there were only 2-3 cases a year. The reason for this was probably the conservative use of radiography as a result of lack of film due to the crisis conditions. The injuries occur far more frequently in men than in women. Of our 58 cases<sup>1</sup> 53 were men and 5 women. The average age of the men was 37 years, and of the women 36 years. The youngest patient, a woman, was aged 17 years, and the eldest, a man, 72 years, at the time of injury (Table I).

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<sup>1</sup> 57 cases from Lund and one case operated on at Varberg Hospital 1945.

TABLE I

58 cases of acute injury to the acromio-clavicular joint,  
verified radiographically at the time of injury (53♂, 5♀).

	No. of Cases	Various Conservative Treatments	Various Surgical Treatments	No. of Cases Followed-up	No. of Cases Re-examined by the Author and Radiographed
Subluxation .	45	44	1	40	10
Luxation . . . .	13	6	7	12	7
Total . . . . .	58	50	8	52	17

Injuries to the acromio-clavicular joint may be divided into 1) *mild injuries*: distraction and subluxation, and 2) *severe injuries*—luxation—where dislocation is complete. The diagnosis is usually easy. The traumatic nature of the milder cases can be verified a few days after injury by the typical discoloration of the skin, due to gravitation haemorrhage into the delto-pectoral triangle area (frequent personal observations). Radiographic examination will give exact information on the degree of dislocation, providing that the exposure is by direct radiation, which can be most easily achieved fluoroscopically (with the arm hanging, to obtain the maximal degree of dislocation). A routine antero-posterior exposure will only show the condition in some cases.

The literature shows that the methods of treatment of acromio-clavicular joint injuries are many and varied. Thus, *Urist* states that there are 35 conservative, and at least 28 operative methods recommended, and notes that very few final results are available. Here in Sweden the usual view would seem to be—with good reason—that *mild injuries* should be treated conservatively, by the simplest method possible, and usually without any attempt at reduction (adhesive strapping and a firm pressure pad over the *lateral* end of the clavicle gives relief in the author's experience). The essential point is that immobilisation of the shoulder joint should be avoided, and from the beginning the patient



Fig. 1.

Abduction cushion used for injuries to the shoulder. (Picture from *Moberg*.)

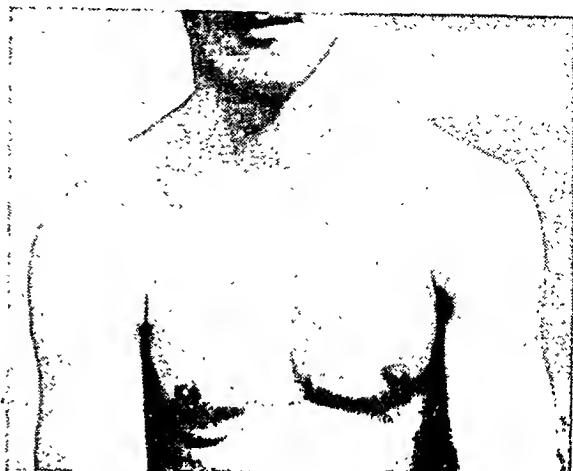


Fig. 2.

Conservatively treated subluxation. At follow-up examination 4 years after the injury, there is visible subluxation of the acromio-clavicular joint.

should receive passive movements of the shoulder joint, and preferably active exercises, if the pain is not too great: that is, *maximal* passive movements in all planes should be obtained once or twice daily. If in these cases the shoulder joint is immobilised for any length of time by strapping, there may be unnecessarily severe after-effects, especially if the patient is elderly, or if the shoulder joint has also suffered a slight *undiagnosed* injury. A *sling* acts as an unspoken reminder to the patient to keep his shoulder joint absolutely still, and should be avoided if possible. An abduction cushion—which for a long time has been called a *Frising* abduction cushion at Lund (fig. 1)—worn day and night is useful, especially when the shoulder joint is also slightly injured. If the patient is instructed to put the cushion and arm up on a table or on the back of a chair when he sits down, a usefully greater degree of abduction is achieved at intervals. Unnecessary surgical interference in these mild cases, such as nailing or wiring, may sometimes increase the length of time for which the patient is disabled, and may lead to permanent disability.

45 of the 58 cases in this material may be described as *mild*. In all cases the subluxation was seen on the radiographs. In 35 cases, upward dislocation of the lateral end of the clavicle was found, and 10 of these 35 showed in addition an abnormal degree of separation between the joint surfaces. In the remaining 10 cases there was only an abnormal degree of separation between the joint surfaces.



Fig. 3.

Man, 29 years, subluxated position immediately after operation.

*Treatment was conservative in 44 cases, and surgical in 1 case.*

*Conservative treatment* varied greatly, probably only partly according to the gravity of the case. A *sling* was used in 10 cases, *adhesive strapping* and a *pressure pad* in 8, an *abduction cushion* in 8, *firm bandaging* in 5, a *Böhler brace* in 3, and *bandaging with cotton wool* in 3. In no case was the arm fixed against the wall of the thorax. In 7 cases no information about the treatment is available. Exact information on the date when exercises were begun, or when passive and active movements of the shoulder joint were allowed, is often missing. Exercises were usually begun as early as possible, often after a week, in several cases at the first visit (e.g. the cases treated by the author during the time he spent at the poly-

clinic) and as a rule without the assistance of a physio-therapist.

*The duration of disability* was recorded for 29 of the 44 patients, and varied between 6 and 80 days, with an average of 23 days.

*39 of the 44 patients with subluxation treated conservatively have been followed-up.*



*Fig. 4.*

Recent total acromio-clavicular dislocation. (Picture from *Usadel*.)

29 were followed-up by questionnaire. All 29 reported complete, or almost complete, recovery from their injury. The only reservations were that they occasionally felt slight pain or inconvenience from the shoulder, and that the arm was not quite as strong as before the accident.

10 patients chosen at random from the 44 treated conservatively have been re-examined by me personally, and the joint area has been radiographed.

In 7 of these 10 the subluxation could be detected when the arms were hanging down and the injured was compared with the sound side (fig. 2). In 2 of these 7 it was easy to palpate part of the joint surface of the lateral end of the clavicle, and in 4 other cases the clavicle was felt to be widened. In no case were the changes enough to be of any



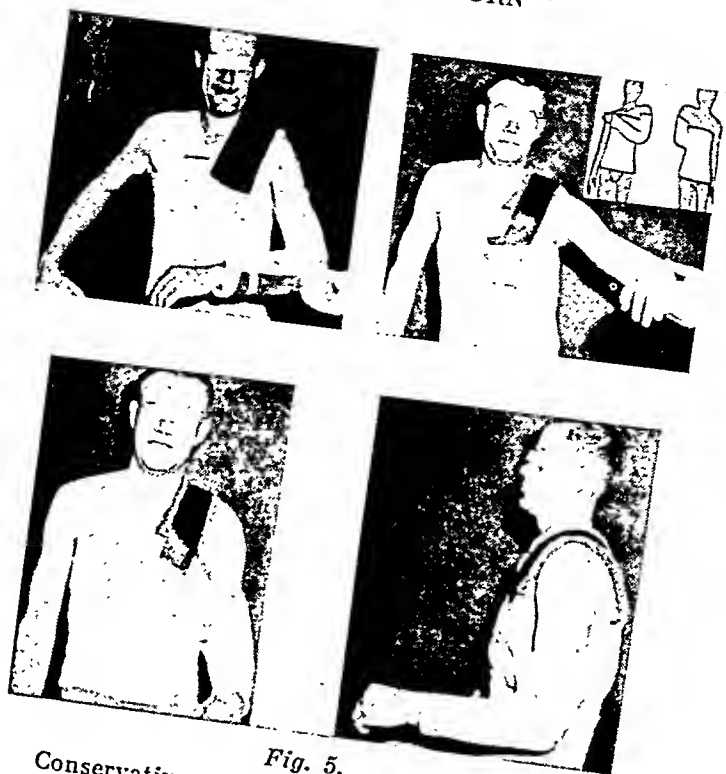


Fig. 5.  
Conservative treatment by Urist's method.

cosmetic importance. If the arm was lifted passively above the horizontal plane, the clavicle could often be returned to its normal position, as judged by palpation and radiography; this was best achieved if pressure was exerted at the same time both forwards and downwards on the lateral end of the clavicle. Mobility of the shoulder joint was in 3 of the 10 cases quite normal, and in 4 cases there was a hardly measurable restriction of rotation which was of no practical importance; it was detected by placing the dorsum of the hand on the back; the thumb of the affected side only reached the angle of the opposite scapula, whereas the thumb of the opposite side reached the base of the spine of the opposite scapula. 2 men, aged 62 and 61 years respectively at the time of injury, both showed a more pronounced limitation of movement at examination 4 years later. Admittedly there was only the slight restriction of rotation as described above,

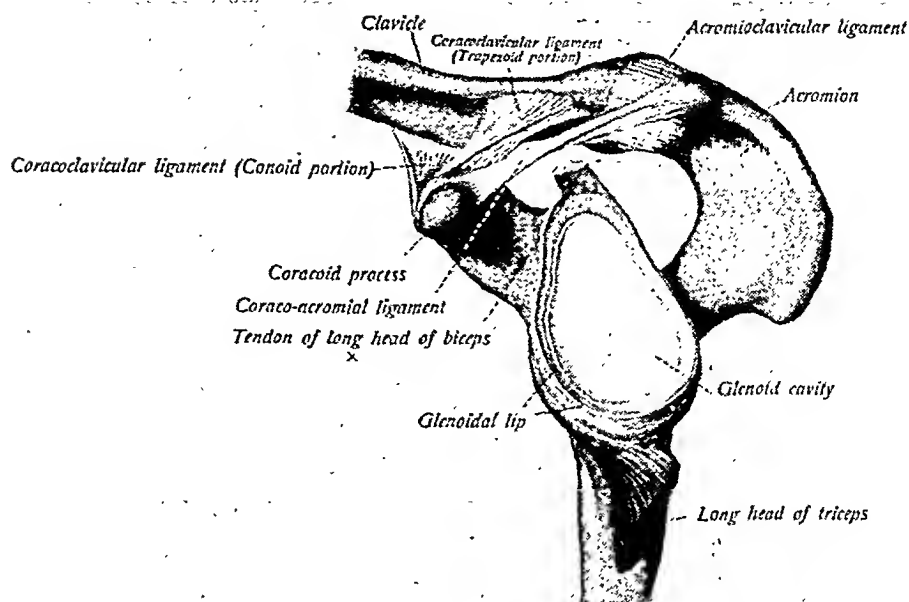


FIG. 579.—SOCKET OF THE LEFT SHOULDER JOINT AFTER REMOVAL OF THE ARTICULAR CAPSULE AND THE TENDON OF THE BICEPS MUSCLE. (Sobotta and McMurrich.)

Fig. 7 a.

Acromio-clavicular region showing ligament. (Picture from Callander.)

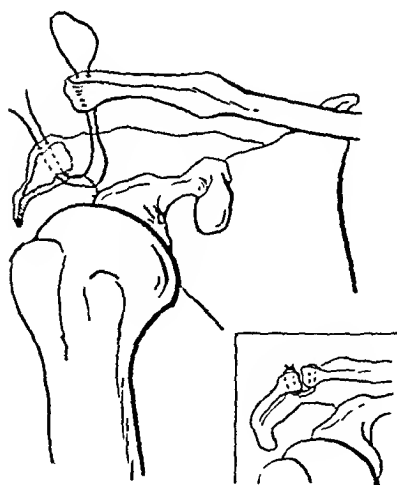


Fig. 6.

Wiring by *Felsenreich's* and  
*Mitchell's* method.  
 (Picture from *Usadel*.)

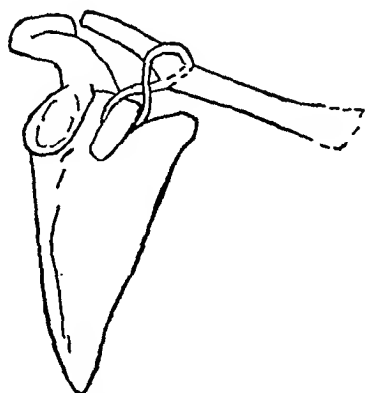


Fig. 7 b.

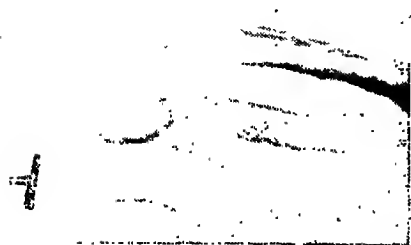
Suture of clavicle to  
 coracoid process.

but they could not raise the arm to more than  $60^{\circ}$  and  $70^{\circ}$  respectively above the horizontal plane. The reason for this limitation in these 2 patients is not clear. Both were declared sound by an insurance company, 46 and 50 days respectively after the accident. The 10th patient, a man aged 65 years, showed considerable limitation of movement of both shoulder joints, secondary to a previously diagnosed chronic polyarthritis (S.R. 101 in 1 hour), and presumably unconnected with the acromio-clavicular injury.

*The case of subluxation* which was treated surgically had an intra-articular operation, and 2 wires were placed mainly extra-articularly. Some degree of subluxation remained after the operation (fig. 3). The patient was discharged as fit for work 37 days after the accident. Soon afterwards a sinus formed over the site of the operation, and healed only after removal of the wires 5 months after operation. Reply to a questionnaire about 10 years after the injury showed him to be fully recovered.

*As was to be expected, the prognosis is good in cases of subluxation of the acromio-clavicular joint, independent of the method of treatment, provided prolonged immobilisation of the shoulder joint is avoided. Surgical treatment is unnecessary. The time needed for treatment depends presumably mainly on the degree of injury, and on possible simultaneous injury to the shoulder joint. It cannot be determined from this material which conservative method of treatment is the most effective for these injuries. The author is inclined to recommend as a standard treatment an abduction cushion, with adhesive strapping and a felt pad on the lateral end of the clavicle, combined with exercises applied from the beginning of treatment; if necessary, because of the pain, at first only passive, and as soon as possible active movement of the shoulder joint. With this treatment, limitation of movement secondary to simultaneous mild diagnosed or often undiagnosed injury to the shoulder joint, is avoided, especially in elderly people.*

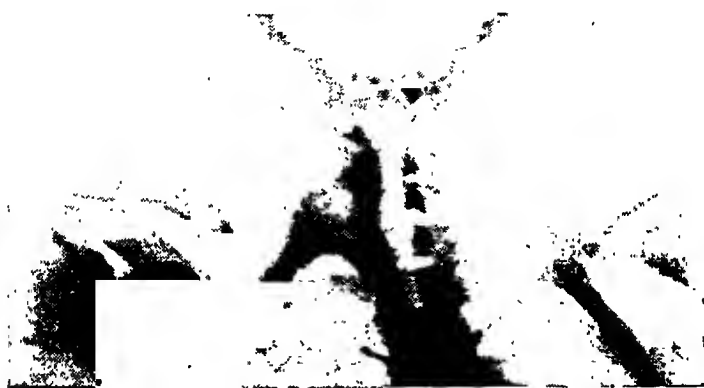
*With regard to severe injuries to the acromio-clavicular joint involving complete dislocation, opinions on conservative*

*Fig. 8.*

Case 1. Total acromio-clavicular dislocation.

*Fig. 10.*

Case 2. Subacromial subluxation immediately after wiring plus free fascia transplantation. Wire intact.

*Fig. 9.*

Case 1. Upward subluxation immediately after catgut suture of ligament plus free fascia transplantation.

or surgical treatment differ. Some authorities hold extreme views, and think that nothing should be done to reduce the dislocation. The functional results are good, and the cosmetic impairment is of no importance to men. This extreme view will hardly be accepted in cases with severe degrees of dislocation, and where the connecting ligaments between the clavicle and the coracoid process have definitely been *completely* torn (figs. 4, 8 and 24).

Conservative treatment involves various types of splinting. The difficulty is to immobilise so that the dislocation is reduced. The simplest, but least efficient, method is by pressure



Fig. 11.

Case 2. Exact contact of joint surfaces after wire has broken.



Fig. 12.

Case 3. Exact contact of joint surfaces after wire has broken.

with a felt pad and adhesive strapping. The safest, but most complicated, method is certainly *Urist's* (fig. 5). According to *Urist*, the plaster shown in fig. 5 should be worn by the patient for 6 weeks. The patients treated by *Urist* in this way were young soldiers on active service. This method of treatment must be considered unsuitable for elderly patients.

*Operative treatment* falls roughly into 2 groups, 1) *intra-* and 2) *extra-articular correction*.

*For intra-articular correction* the joint is opened. Arthrodesis (*Cooper* 1856), with resection of the joint surfaces, can be performed. Usually, however, the joint surfaces are preserved, and fixation is obtained in a variety of ways, for example, by a nail hammered in from the acromion across the joint to the clavicle, or by some kind of thread placed in various positions (wire, silk, fascia). *Felsenreich's* and *Mitchell's* wiring (strictly speaking applied extra-articularly), appears to the author to be one of the most reliable methods, and perhaps the one that gives the best chance of future function of the acromio-clavicular joint (fig. 6). *Odelberg* has used a similar method.

*In the extra-articular operation*, the joint is left intact during the rougher handling, but it is opened during the operation; the capsule ligaments are sutured with catgut. If an articular disc is found it is removed, if necessary. The basic purpose of the operation is reconstruction of the torn ligaments between the clavicle and the coracoid process (the

*Fig. 13.*

Case 1. Calcification of soft tissue in the injured area 4 weeks after catgut suture of ligaments plus free fascia transplantation.

*Fig. 14.*

Case 1. Widespread calcification of soft tissue in injured area 2½ months after operation.

trapezoid and conoid ligaments, fig. 7 a). This can be done in different ways. The ruptured ligaments may be sutured. The stumps of the ligaments are, however, very short, the sutures are difficult to place and will not hold, especially under the strong mechanical strain to which they are exposed immediately after operation. As a substitute for the torn ligaments the acromio-coracoid ligament can be used, the whole of the acromial insertion being transferred to the clavicle. Fixation of the clavicle to the coracoid process can finally be achieved in various ways, by wiring (see *Bergh*, for example) or by free fascia transplantation (fig. 7 b).

In 1942 the author treated a case of severe dislocation of the acromio-clavicular joint, where all the connecting ligaments between the clavicle and the coracoid process had been ruptured (fig. 8). The dislocation was easily reduced, so conservative treatment was tried first. However, the dislocation soon recurred under the bandages (a pressure pad and adhesive strapping, and later firm bandaging of the upper arm to the wall of the thorax) and it was felt that operation was indicated. When it came to a choice of operative method, the author recalled a number of cases in which an intra-articular operation had had relatively unfavourable results, both anatomically and functionally.

A study of the literature, in which *Usadel's* comprehensive

work the most useful, showed that from all points of view the functional operation in cases where direct suture of the ligaments was impossible was to transplant free fascia as a substitute for the torn ligaments between the coracoid process and the clavicle. At operation the dislocation could be completely reduced, and the torn ends of the ligaments were sutured with catgut, and secured by free fascia lata transplants: a 1.5 cm wide strip of fascia was looped round the clavicle, and both ends were sewn to the coracoid process. Radiography directly after the operation showed upward subluxation for half the width of the bone (fig. 9). In view of this subluxation immediately after the operation, the author modified his technique in the 2 subsequent operations, thus, in addition to suture of the ligaments and fascia transplantation, the clavicle was fixed to the coracoid process by a metal wire from the clavicle round the coracoid process. In all 3 cases the report on the operation states that the reduction of the dislocation was complete. In the 1st case a supra-acromial subluxation was found immediately after operation (fig. 9). In the 2nd case, which was wired, radiography after the operation showed over-correction, with a sub-acromial subluxation (fig. 10). Then the metal wire broke, and radiography showed a correct position (fig. 11). In the 3rd case a correct position was found after the wire had broken (fig. 12). The simplest way to interpret these findings is that the author's idea of the correct position during operation, was all right in all 3 cases, but when the arm was adducted towards the thorax after the operation, the strain on the plastic ligament was considerably increased. Normally, according to *Sommer*, the coraco-clavicular ligament will stand a stress of 80 kgms (appr. 176 lbs.). A supra-acromial subluxation appeared in case 1. In cases 2 and 3, the wires held at first and an over-corrected subacromial subluxation position was obtained (radiographic confirmation in case 2, fig. 10). Thus, when the wire breaks under the great strain, the subacromial subluxation is reduced to the correct position (fig. 11). The wire should therefore not be pulled too tight, and the surgeon



Fig. 15.

Case 1. Barely visible subluxation of right acromio-clavicular joint, 5 years after free fascia transplantation.

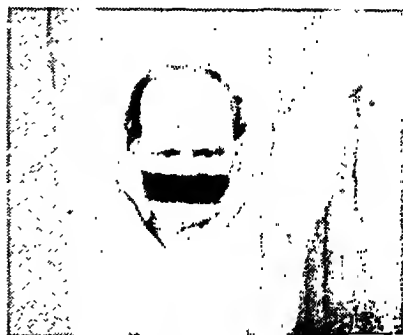


Fig. 16.

Case 1. Follow-up examination 5 years after operation. The slight limitation of movement is in the sound shoulder joint.

should, during the operation, check what the position will be when the arm is adducted against the lateral wall of the thorax. *Bergh* described 6 cases operated on by wiring between the clavicle and the coracoid process. The wire broke after the operation in 4 cases.

*The post-operative course* was smooth in all 3 cases. The first patient was put in a thoraco-brachial plaster, with the arm free in an abducted position. The arms of the other 2 patients were held in abduction by an abduction cushion. In all 3 cases passive and active exercises were begun very early (as soon as the wound showed normal healing). They were discharged as fit for work 2, 3 and 1 months respectively after the operation. All 3 were insurance cases. In this connection one may mention *Krieger Lassen's* striking statement that in 52 cases (18 hospitalised, 9 operated) of luxation of the acromio-clavicular joint there was 5-29 months interval between the injury and assessment of the disablement (average 10 %) by the Danish Workers Insurance Board.

*Case 1.* Man aged 51, building labourer (case history no. 3883-42) 18/10 fell from bicycle. Unconscious for several minutes. Felt unwell. Admitted to hospital 19/10: Superficial flesh wounds on right shoulder. Pronounced upward dislocation of lateral end of right clavicle. Radiography: Dislocation of acromio-clavicular joint, with lateral end of clavicle displaced upwards by twice the breadth of the bone (fig. 8).



*Arthrosis deformans in the Acromio-Clavicular Joint at the Time of Injury and at Follow-Up Examination.*

At the Time of Injury				At Follow-Up Examination						
Age in years	No bilateral arthrosis deformans	Slight bilateral a. d.	Marked bilateral a. d.	Years under observation	No bilateral a. d.	Slight bilateral a. d., equal on the two sides	A. d. increased equally on the two sides	No a. d. on sound side, slight on injured side	Slight a. d. on sound side, increased on injured side	Slight bilateral a. d. more severe on sound side
21	1			4	1					
23	1			4	1					
21	1			4	1					
62		1		4			1			
65		1 <sup>1</sup>		5			1			
52		1		4					1	
47	1			10						
25	1			8		1				1
<i>8 Cases of Subluxation Treated Conservatively</i>										
34	1			9	1					
27	1			9				1		
<i>2 Cases of Dislocation Treated Conservatively</i>										
58		1		10						
23	1			8				1		
<i>2 Cases of Dislocation Treated by Intra-articular Operation</i>										
<i>2 Cases of Dislocation Treated by Fascia Transplantation</i>										
51		1		5			1			
65			1	3			1			

<sup>1</sup> At the time of injury showed more severe arthrosis deformans on the sound side.



Fig. 17 a & b.

Case 1. Calcifications and ossification of injured area 5 years after free fascia transplantation.

*Fixation with adhesive strapping and pressure pad. Radiography: Perfect alignment.* 21/10: Radiography: Redislocation by breadth of bone; fixation completed by firm bandaging of the upper arm against the thorax. 24/10: Radiography: Redislocation unchanged. 28/10: *Open reduction plus fixation of clavicle to coracoid with free fascia transplantation by the author.* N<sub>2</sub>O + Ether Anaesthesia given. The ends of the coraco-clavicular ligament caught with catgut sutures. Complete reduction occurs easily. Sutures: Fascia lata strip about 15 cm × 1.5 cm placed round clavicle and both free ends sewn to coracoid. Apparent effective and exact fixation. Suture of capsular ligaments on superior and anterior aspects of acromio-clavicular joint. No articular disease. 28/10: *Radiography after operation:* upwards subluxation by the width of half a bone (fig. 9). 13/11: Scar healed by first intention. Thoraco-brachial plaster cut away superiorly. Exercises given. Discharged. *Out-patient re-examinations:* 30/11: *Radiography:* calcification of soft tissue between coracoid process and lateral end of clavicle (fig. 13). 28/12: satisfied, to begin light work. 11/1 1943: Almost full mobility in shoulder-joint: *Radiography:* unchanged position. Widespread calcification of soft tissue (fig. 14). 15/2: No visible deformity. Normal mobility. *Follow-up examination* 16/9 1947: Feels no pain. Does very heavy work. Barely visible and palpable subluxation (fig. 15), increased width of lateral end of clavicle. Completely normal mobility (fig. 16). No crepitus. Radiography: lateral end of clavicle forming acromio-clavicular joint subluxated by half the width of the joint. Under this is found an irregular bony process 6 cm long and 2 cm wide, connected with the clavicle. It extends to the coracoid process, but is not in bony connection with it (fig. 17a & b).

*Case 2.* Man aged 65. Warehouse worker (case history 4840/44). 13/11 fell from height of 2 metres (7 ft.). Admitted 14/11: Pronounced upward dislocation of right acromio-clavicular joint. Restricted mobility of shoulder joint. Radiography: dislocation of acromio-clavicular joint with displacement of lateral end of clavicle by twice the width of the bone.



Fig. 18.

Case 2. Limitation of extension  
3 years after wiring plus free  
fascia transplantation.



Fig. 19 a & b.

Case 2. Calcifications and  
bone bridge between clavicle  
and coracoid process, 3 years  
after wiring and free fascia  
transplantation.

15/11: *Open reduction and clavicle-coracoid fixation by metal wire and free fascia transplantation by the author.* The stumps of the coraco-clavicular ligament secured with one linen and one catgut suture. A metal wire, looped round the coracoid process and through hole drilled in lateral end of clavicle, was tightened and tied, using *Sven Johansson's* apparatus, to produce exact alignment of the acromio-clavicular joint. Ligament sutures tied. Fascia lata strip about 15 cm×1.5 cm placed round clavicle and coracoid process, and sutured in this position. Otherwise operation as above. 21/11: Radiography: Sub-acromial subluxation in the acromio-clavicular joint (fig. 10). 23/11: Exercises begun. 2/12: Wound healed. *Aspiration* of 30 c.c. serous fluid from area of operation. Fairly good mobility: abducts arm to 45° above horizontal plane. Rotation 45°. Discharged. *Out-patient examinations* 6/12: Reaspiration. 12/12: Physical treatment continued twice weekly. 18/12: Radiography: Wire broken in two places. Practically exact alignment of the joint. Calcification of soft tissue (fig. 11). 12/1 1945: Physical treatment once a week. 23/2: Good mobility. Discharged as fit. 13/6 1945: Occasional pain round right shoulder. Movements normal. No pain on movement. *Final examination* 18/9 1947: Oc-



Fig. 20 a, b and c.

Case 3. Range of movement 2 years after wiring and free fascia transplantation.

casional slight discomfort in shoulder. On full work as warehouse worker, lifting and carrying sacks, etc. No visible or palpable subluxation. Lateral end of clavicle increased in width. *Mobility*: With arms stretched overhead, about  $10^\circ$  limitation of movement (fig. 18). Rotation normal, except for internal rotation: if the dorsum of the hand is placed on the back, tip of right thumb reaches only 10 cms below the angle of the scapula. Slight crepitus round right shoulder joint. Radiography: *Right shoulder*: Exact alignment of acromio-clavicular joint. Since previous examination 18/12 1944, calcification of area between clavicle and coracoid process further increased. Both bones now connected by bony bridge. A fairly long area of calcification found along the acromial insertion of the coracoid ligament. The broken wire remains in the same position (fig. 19 a & b). *Left shoulder*: Some arthrosis deformans in acromio-clavicular joint.

Case 3. 36 year-old man. Dairy-farm foreman. Admitted Varberg Hospital 7/12 1945. Fell from bicycle same day. Lateral end of left clavicle dislocated upward, with 2 cms. palpable separation from the acromion. Radiography: Dislocation of acromio-clavicular joint, with lateral end of clavicle displaced upward by more than the width of the bone. 11/12: Operation (no. 1335) by author. Open reduction with fixation of clavicle to coracoid by wire and free fascia transplantation. Operation performed exactly as in case 2, except that fascia transplantation was looped round clavicle and coracoid process as figure-of-8. 22/12: Scar healed by first intention. Exercises begun early. Continuing abduction



*Fig. 21.*

Case 3. Calcifications and bone bridge between the clavicle and the coracoid process, 2 years after wiring and free fascia transplantation.



*Fig. 22.*

Man, now 37 years of age, after conservative treatment. 10 years after injury visible subluxation of acromio-clavicular joint.



*Fig. 24.*

Man, now 43 years old, showing dislocation 9 years after injury treated conservatively with pressure pad and adhesive strapping.

cushion. Discharged. *Out-patient re-examination:* 14/1 1946: Normal mobility. *Radiography:* Wire broken in one place. Joint surfaces in exact alignment (fig. 12). Discharged as fit. *Follow-up examination 25/10 1947:* Feels perfectly well. Can do all sorts of work, carry heavy sacks, etc. on left shoulder. No visible or palpable subluxation. Lateral end of clavicle increased in width. Mobility normal (see fig. 20 a, b & c). No erepitation. *Radiography:* Loop visible between clavicle and coracoid process; is broken. Lateral end of clavicle now connected with lateral aspect of coracoid process by rather irregular ribbon-like bony formation. Small areas of calcification found between the tip of the coracoid process and the lateral aspect of the clavicle. Position of bones of the acromio-clavicular joint correct (see fig. 21).



*Fig. 23.*

Man, now 37 years of age. Calcifications 10 years after injury treated conservatively with pressure pad and adhesive strapping.



*Fig. 25.*

Man, now 43 years old. Calcifications 9 years after injury treated conservatively with pressure pad and adhesive strapping.

*Thus at follow-up examination during September-October 1947 the 3 cases showed good anatomical and functional results roughly 5, 3 and 2 years respectively after operation. There was no visible or palpable subluxation, except to an insignificant degree in case 1 (fig. 15). In all 3 cases the lateral end of the clavicle could be felt to be definitely widened. All 3 patients were engaged in heavy manual labour. 2 showed an absolutely normal range of movement on both sides (the deficient mobility shown in fig. 16 is confined to the side not operated on). Case 2, a 65 year-old man, had a mild limitation of abduction (see fig. 18), and slight limitation of rotation could be detected when he placed the dorsum of the hand on his back; the tip of the thumb on the operated side only reached 10 cms (4") below the angle of the scapula, while that of the sound side could reach up to the angle of the scapula. Judging from these 3 cases operated for total dislocation of the acromio-clavicular joint, the extra-articular method, using fixation with wire and free fascia transplants, as applied in the author's cases 2 & 3, can be recommended. It is, however, essential that the patient should be given passive and active exercise of the shoulder joint, preferably beginning during the first week after operation. Good anatomical as well as functional results can then be expected.*



Fig. 26.

Man, 58 years of age. Redislocation immediately after suture of joint capsule.



Fig. 27.

Man, now 68 years old. Suture of joint capsule. 10 years later: calcifications.

*Of the 10 cases of complete dislocation which, apart from the 3 previously mentioned, are included in the material, 6 were treated conservatively, all with pressure pad and adhesive strapping. Incapacity for work varied between 21 and 75 days. The average was 45 days.*

5 of these 6 patients have been followed-up later by questionnaire. 8-9 years after the injury 3 patients claimed to have recovered fully, and do not mention any dislocation. The 4th patient, a teacher, states in his letter that 9 years after the accident his injured arm is less strong, and will not stand prolonged strain. The dislocation remains unchanged, and during "some" movements the clavicular dislocation reduces itself spontaneously. Normal range of movement. The 5th patient, an officer, states that 10 years after the accident he has no complaints about his ability to work and move his arm, but that the outer end of the collar bone is displaced upward from the joint (fig. 22). Radiography 3/5 1948 (fig. 23). The 6th patient has been examined by the author 9 years after the accident. Dislocation is clearly visible. The patient can increase the dislocation (fig. 24) and it can be partly reduced by manipulation if the arm is raised above the horizontal plane. Palpation shows increased width of the lateral end of the clavicle. His arm does not feel quite as strong, but he has no pain. The range of movement is nearly normal; rotation is still somewhat limited. When he puts his right hand on the



*Fig. 28.*

Man, 23 years old. Redislocation 1 month after wiring clavicle to acromion.



*Fig. 29.*

Man, now 31 years old. 8 years after operation: calcifications. Wire has broken.

back of his neck, the tips of his fingers reach just in front of the left outer ear (the left reaches the right corner of his mouth), and with the dorsum of the hand placed on the back, the tip of the right thumb reaches to the angle of the scapula (the left reaches as high as the base of the spine of the scapula). Radiography: 28/1 1948 (fig. 25).

*The 4 patients with complete dislocation, treated surgically, all had intra-articular operations.*

*In 2 cases, the operation consisted only of suture of the joint capsule with catgut, giving in the first case normal alignment, in the second a redislocation, seen on the radiographs taken immediately after the operation (fig. 26). The post-operative course was uneventful. The 1st patient, a medical student, was considered unfit for 3 weeks after the operation. 3 months later he fractured the lateral end of the clavicle on the same side. At follow-up examination by letter, 9 years after the accident, there was said to be an abnormal palpable separation of the joint surfaces. The lateral end of the clavicle was increased in width, and the acromion was lying 1/2 cm below the clavicle, compared with the sound side. He had slight pain, and his arm tired more easily after, for example, carrying loads with the arm hanging. The 2nd patient, a bricklayer, who had a redislocation, was disabled for about 4 months, after which he was discharged with a certifi-*





*Fig. 30.*

Man, 53 years old. Intra-articular operation by *Felsenreich's* method and fixation with *Rissler* pin.



*Fig. 31.*

Man, now 69 years old. Conservative treatment. 5 years after injury: bridge type of calcification of conoid ligament.

cate of disablement. The insurance company granted him a disablement pension for 1 year on the basis of a 10 % reduction of capacity for work. *At the follow-up examination* by the author 10 years after the accident, the dislocation could be clearly seen and palpated. The lateral end of the clavicle had increased to double its width. Occasional pain in the shoulder was felt in connection with heavy work. The lifting capacity was equal on the two sides. Normal range of movement. Radiography: 18/5 1948 (fig. 27).

*In 2 cases* the end of the clavicle was wired to the acromion. In the first, radiography, well over one month after the operation, showed that the wire was no longer attached to the acromion, and the dislocation had recurred (fig. 28). Incapacity for work after the operation lasted well over 2 months in this case. *At follow-up examination* 8 years after the accident, a subluxation was clearly seen and palpated. The lateral end of the clavicle had increased to double its width. Occasionally he felt tired and had slight pain in the arm. Lifting capacity and range of movement were normal. Radiography: 18/5 1948 (fig. 29).

*The 4th and last case* was treated by wire fixation by *Felsenreich's* method, combined with fixation with a *Rissler's* metal pin (fig. 30). Radiography 2½ months later showed no



*Fig. 32.*

Man, now 27 years old. Conservative treatment. 4 years after injury: calcification of trapezoid ligaments and conoid ligament joined to the coracoid process by bone: also hook-shaped process on the lateral end of the clavicle inferiorly.



*Fig. 33.*

Man, now 27 years old. Conservative treatment. 4 years after injury: lateral end of clavicle pointed like a beak.

change of position and he was allowed to start light work. No further information about this patient is available.

*From these 10 cases of complete dislocation of the acromio-clavicular joint, it would appear that, whether treatment has been conservative, using adhesive strapping and a firm pressure pad, or surgical, using various types of intra-articular operation, the anatomical result is usually poor. The important fact, however, is that the functional result is good.*

#### RESULTS OF RADIOGRAPHIC FOLLOW-UP EXAMINATION

17 of the 58 cases forming the material have been radiographed later (16 of the cases at Lund diagnostic X-ray department, and one case at Visby Hospital X-ray department).

*Areas of calcification in the injured area have been seen with great frequency, i.e. in 14 out of the 17 cases examined.*

*Krieger Lassen, Schnek, Svab, Usadel, Urist, Wahren, and others have described similar post-traumatic calcified areas. According to Svab, Grune and Meyer have each published descriptions of 2 cases, in 1911 and 1912 respectively, and Hart-*

*mann* and *Poirier*, the anatomists, showed as long ago as 1887 similar formations in their anatomical specimens.

Calcifications may occur in different ways.

- 1) By periosteal new bone formation on the clavicle or coracoid process, or from fragments of periosteum detached from these bones.
- 2) By a calcification process in the coraco-clavicular ligament.
- 3) By calcareous deposits in devitalised tissue (remains of ligaments, transplanted strips of fascia, haematomata and bursae).

*Svab* found calcified areas of varying sizes in the coraco-clavicular ligament, in 15 out of 22 cases of long-standing acromio-clavicular dislocation. *Svab* believes that the calcification arises through a process of ossification deriving from the cartilaginous or true cartilage tissue on the outer surface of the ligament, which *Luschka*, *Poirier* and *Fick* demonstrated. *Svab* also thinks that there may be a connection between the extent of the ossification and the degree of damage to the vessels caused by the injury to the ligament.

*Urist* found calcification in 18 of 41 cases examined—this was restricted to the coraco-clavicular ligament. Macroscopic and radiographic examination of extensive areas of calcification excised in chronic cases treated by resection of the lateral end of the clavicle, showed that it sometimes appeared as a bony spur from the periosteum on the clavicle or coracoid process. In other cases it was found as an independent formation.

3 of the 17 cases forming the material showed no calcifications on the follow-up radiographs. These 3 cases are from the group of *cases of subluxation treated conservatively*. The areas of calcification in the remaining 7 *cases of subluxation treated conservatively* appear in various forms, namely calcification of the trapezoid ligament in 4 (in 2 of these it is restricted to the area of insertion on the lateral end of the

clavicle and in 2 to the insertion on the coracoid process). Similarly the conoid ligament shows calcification in 4 cases; restricted in 2 cases to the insertion on the lateral end of the clavicle, and in 1 case to the insertion on the coracoid process. *In the 4th case there is a calcified bridge between the clavicle and coracoid process* (fig. 31). In 2 cases areas of calcification have been seen in and round the acromio-clavicular joint. *In 1 of these the calcification on the coracoid process shows a bony structure* (fig. 32).

All 7 cases of dislocation, whether treated conservatively or surgically, show abnormal calcification of the injured area at the follow-up examination.

The 2 treated conservatively show calcification, localised in both cases to the insertion of the trapezoid ligament on the clavicle and to its central area, as an isolated, independent calcified area (figs. 23 and 25). In one case the insertion of the conoid ligament onto the coracoid process is also calcified (fig. 23).

The 2 treated by intra-articular operation show areas of calcification, localised in one case to the clavicular end of the trapezoid ligament and an independent insular area in the centre of the conoid ligament (fig. 29), in the other to the insertion of the trapezoid ligament onto the coracoid process as well as to the neighbouring area of the acromio-clavicular joint (fig. 27).

The 3 treated by free fascia transplantation all show calcification localised to the fascial transplant (figs. 17, 19 and 21). All these areas show bony structure and also there is calcification of the clavicular end of the trapezoid ligament, and in one there is also calcification of its insertion onto the coracoid process (fig. 21). In all 3 the fascial transplant was so placed that, to a great extent, it coincides with the line of the conoid ligament, for which reason it is not possible to determine whether there is also calcification in this ligament. In one of the 3 cases (case 2), the bony connection between the coracoid process and the clavicle is wide enough to justify a presumption that material from the conoid ligament is included in the

bony bridge (fig. 19). In case 3 it is uncertain whether the ligament is included in the bony bridge (fig. 21). In case 1, where a bony connection is not found between the coracoid process and the clavicle, it is clear from the width of the calcified area that the clavicular end of the conoid ligament is calcified (fig. 17).

A study of the radiographs of these 3 cases illustrates the author's method of placing the transplantation. In all 3 the loop of fascia was placed round the clavicle, and the bony bridge can be seen on the radiograph to be attached to the clavicle in all cases (figs. 17, 19 and 21). In case 1 the two free ends of the transplant were attached to the coracoid process, anteriorly and posteriorly, respectively. In this region no bony connection has appeared (fig. 17). In the 2 other cases, the loop of fascia was placed round the clavicle as well as the coracoid process, and a complete bony connection has developed: that is, a bridge of bone between the coracoid process and the clavicle (figs. 19 and 21). In case 3 the middle of the bridge is narrow, probably because the loop of fascia was placed as a figure-of-8 round the clavicle and coracoid process (fig. 21).

*Bony connection between the clavicle and the coracoid process* is thus found in 3 of the author's cases; in 2 of which fascia transplantation was used (figs. 19 and 21), and in 1 subluxation treated conservatively (fig. 31). *Urist* has also found bony connections in cases treated conservatively.

*Urist* found that calcification could be seen as early as 3-4 weeks after injury. It increased in area and intensity as the months went by. The final extent varied from a small patch of calcification to the bony union between the clavicle and coracoid process just described. In the author's surgically treated material, minimal calcification could be found as early as 1 month after operation (fig. 13), and 2½ months after operation it had assumed its final form and extent, even though the calcium content was still low (fig. 14). Like the author, *Liberson* and *Birkett* have found calcification after fascia transplantation—each in one case.

It is impossible to say why calcification does not occur in every case of acute injury to the acromio-clavicular joint. Calcification may appear whether the injury is mild or severe, and whether the treatment is conservative or surgical. Nutritional conditions would seem to play an important part in calcification of the transplanted fascial strip. The patient's age at the time of injury is not of decisive importance. 3 patients from the author's material, in which calcification did not occur, were 25, 47 and 61 years respectively at the time of injury. Among the conservatively treated patients showing calcification were 3 aged 21-23 years, and 4 aged 45-65 years at the time of injury. Among the patients showing calcification who had intra-articular operations, 3 were aged 23-34 years, and 1 58 years. The 3 patients treated by fascia transplantation, were aged 36, 51 and 65 years respectively at the time of injury.

The functional result is not influenced by calcification. Of the 3 cases in the author's material where the functional result proved poor (conservatively treated cases of subluxation, see pp. 355-56) calcification is absent in one (man aged 61 years), but appears in the 2 others (men aged 62 and 65 years).

14 of the cases which were examined radiographically can be used to throw light on the question of whether any connection can be found between acromio-clavicular joint injuries and arthrosis deformans in this joint. The result will be found summarized in Table II. In 6 cases an arthrosis either occurred after the injury, or increased in intensity on the injured side. In 2 of these, however, the facts are not so simple. In one case the arthrosis changes were from the beginning more marked on the sound side; later, at the follow-up examination 5 years after the accident, it was about equal on the two sides. In the 2nd case there was no arthrosis on either side at the time of injury. 10 years later, the patient showed slight bilateral arthrosis, but with rather more marked changes on the sound side. The result of the investigation is thus ambiguous. In some cases (in 4 of the 14 cases forming

the material), there is a possibility that the arthrosis changes occurred or increased as a result of the accident.

Radiographic changes have been shown in 3 more cases. In 2 cases, aged 23 and 45 years respectively, the lateral end of the clavicle has become pointed and beak-shaped since the accident (fig. 33), and in 1 case a hook-shaped process has formed below the lateral end of the clavicle (fig. 32).

### SUMMARY

The results of treatment of 58 cases of acromio-clavicular joint injuries from Lund Surgical Clinic are reported.

44 mild injuries—subluxation of the acromio-clavicular joint—have been treated conservatively, and 1 surgically. Incapacity for work lasted on an average 23 days. The prognosis is usually good, independent of the method of treatment, provided that immobilisation of the shoulder joint is avoided. The author is inclined to recommend as a standard method an abduction cushion with a pressure pad and adhesive strapping on the lateral end of the clavicle, combined with physical treatment begun at the beginning of treatment; if necessary because of the pain only passive movements need be given at first, and active movements of the shoulder joint are begun as soon as possible. With this method of treatment, restriction of movement secondary to a mild injury to the shoulder joint, diagnosed or undiagnosed, is avoided, especially in elderly people. Surgical treatment is unnecessary.

Of 13 more severe injuries—dislocation of the acromio-clavicular joint—6 have been treated conservatively, using pressure pad and adhesive strapping, and 7 surgically. The period of incapacity for work averaged 45 days for the cases treated conservatively, and 65 days for the cases treated surgically.

3 patients have been operated on extra-articularly, using a free fascia transplant as a substitute for the torn coracoclavicular ligament (plus wire fixation in 2 of the 3 cases). 4 have been operated on intra-articularly by different methods. The follow-up examination showed that the functional result

was good in all cases of dislocation, whether they were treated conservatively or surgically. The anatomical result was usually poor in all the cases treated conservatively, and in the cases who had intra-articular operations. A good result, both functional and anatomical, was recorded 5, 3 and 2 years respectively after free fascia transplantation. In the 2 last cases to be operated on, the author used a free fascia transplant and wiring, and this method is recommended for severe cases of dislocation where the ligamentous connection between the clavicle and the coracoid process proves to be completely divided. An abduction cushion and early exercises are recommended.

Abnormal calcification of the injured area has been observed in 14 out of the 17 cases re-examined radiographically.

Calcification appears whether the injury is mild or severe, and whether the treatment is conservative or surgical. It can be observed as early as 3-4 weeks after the accident, according to the observations of the author and others, and it may have assumed its final form and extent  $2\frac{1}{2}$  months after the accident. The calcification may have a bony structure and may form a bridge between clavicle and coracoid process, whether the treatment is conservative or surgical. The patient's age at the time of injury has no proven influence on the appearance of calcification. The calcification does not affect the later functional result.

The calcification may be localised to various parts of the coraco-clavicular ligament, to various positions in various cases, and to the area of the acromio-clavicular joint. The extent varies widely from a small patch of calcification to a number of extensive areas in the region of the injured area. In the cases treated by free fascia transplantation, the calcification has in all cases a bony structure, and is mainly localised to the transplanted strip.

With regard to the question of a relation between arthrosis deformans and acute injuries to the acromio-clavicular joint, the author's material shows that it is possible that arthrosis changes have occurred or increased as a result of the injury.



## RESUMÉ

Les résultats du traitement de 58 cas de lésions de l'articulation acromio-claviculaire de la Clinique Chirurgicale de Lund sont rapportés.

44 lésions peu graves — subluxation de l'articulation acromio-claviculaire — ont été soumises à un traitement conservateur, et 1 chirurgical. Il y a eu incapacité moyenne de travail pendant 23 jours. Le pronostic est généralement bon, indépendamment de la méthode de traitement, à condition d'éviter l'immobilisation de l'articulation de l'épaule. L'auteur est enclin à recommander comme méthode standard un coussin d'abduction avec coussin de pression et rattachement adhésif à l'extrémité latérale de la clavicule, combinée, à un traitement physique institué dès le début: si nécessaire par suite de douleurs, on peut se borner pour commencer à des mouvements passifs, mais il convient de commencer dès que possible les mouvements actifs de l'articulation de l'épaule. Avec cette méthode de traitement on évite, notamment chez les personnes âgées, une restriction des mouvements, secondaire à une lésion bénigne de l'articulation de l'épaule diagnostiquée ou non diagnostiquée. Le traitement chirurgical n'est pas nécessaire.

Sur 13 lésions sévères — dislocation de l'articulation acromio-claviculaire — 6 ont été soumises à un traitement conservateur en utilisant un coussin de pression et le rattachement adhésif, 7 à un traitement chirurgical. La période d'incapacité de travail s'est étendue en moyenne sur 45 jours pour les cas soumis au traitement conservateur, à 65 jours pour ceux traités chirurgicalement.

3 malades ont été opérés extra-articulairement, en utilisant la transplantation d'une fibre l'aponevrose femorale pour remplacer le ligament coraco-claviculaire déchiré ( et fixation par fil métallique dans 2 de 3 cas ). 4 cas ont été opérés intra-articulairement par diverses méthodes. Les examens subséquents ont fait ressortir un bon résultat fonctionnel dans tous les cas de dislocation, qu'ils aient été soumis à un traitement conser-

vateur ou chirurgical. Le résultat anatomique était généralement médiocre aussi bien dans les cas soumis au traitement conservateur que dans ceux opérés intra-articulairement. Un bon résultat, tant au point de vue fonctionnel qu'anatomique, a été enregistré 5, 3 et 2 ans respectivement après la transplantation de l'aponevrose. Dans les 2 derniers cas opérés, l'auteur a utilisé fixation par transplantation de l'aponevrose femorale et fil métallique et cette méthode est recommandée pour les cas graves de dislocation ou l'on constate que l'attache ligamenteuse entre la clavicule et l'apophyse coracoïde est complètement rompue. On recommande un coussin d'abduction et des exercices pratiqués à un stade précoce.

Une calcification anormale de la partie de la lésion a été observée dans 14 des 17 cas réexaminés à la radiographie.

La calcification apparaît que les cas soient bénins ou graves et que l'on ait institué un traitement conservateur ou chirurgical. On peut l'observer déjà 3 à 4 semaines après l'accident, suivant les observations de l'auteur et d'autres et on suppose qu'elle a atteint sa forme et son extension définitives 2½ mois après l'accident. La calcification peut avoir une structure osseuse et former un pont entre la clavicule et l'apophyse coracoïde, que le traitement ait été conservateur ou chirurgical. Il n'a pas été prouvé que l'âge du malade au moment de la lésion influe sur le développement de la calcification. Celle-ci n'affecte pas le résultat fonctionnel tardif.

La calcification peut être localisée dans les diverses parties du ligament coraco-claviculaire, dans des positions variées dans les différents cas et dans la région de l'articulation acromio-claviculaire. Son extension diffère beaucoup, elle peut passer d'une petite tache de calcification à de nombreuses plaques qui s'étendent sur toute la région de la lésion. Dans les cas traités par transplantation, la calcification a toujours eu une structure osseuse et était principalement localisée au lambeau transplanté.

En ce qui concerne la question d'un rapport entre l'arthrosis deformans et les lésions aiguës de l'articulation acromio-claviculaire, les observations de l'auteur montrent qu'il est

bien possible que des modifications d'arthrosis se soient développées ou accentuées à la suite de la lésion.

### ZUSAMMENFASSUNG

Das Behandlungsergebnis in 58 Fällen von acromioclaviculär Schäden, behandelt an der chirurgischen Klinik in Lund wird mitgeteilt.

44 leichtere Schäden — subluxatio acromioclavicularis — wurden konservativ, und einer operativ behandelt. Die Arbeitsunfähigkeit betrug im Durchschnitt 23 Tage. Das Endresultat ist in der Regel ein gutes vorausgesetzt dass man die Fixierung im Schultergelenke vermeidet. Der Verfasser empfiehlt als Normalmethode Abduktionsschiene und Pelotte-Heftpflasterverband über dem lateralen Clavicularende mit Bewegungstherapie. Mit der letzteren beginnt man direkt vom ersten Tage der Behandlung, wenn die Schmerzen es vorschreiben zuerst mit passiven Bewegungen, doch so bald als möglich mit aktiven Bewegungen im Schultergelenk. Durch ein solches Regime verhindert man vor allem bei älteren Menschen eine Einschränkung der Beweglichkeit im Schultergelenk, die sekundär infolge einer gleichzeitig entstandenen diagnostizierten oder nicht diagnostizierten Schultergelenksschädigung auftreten kann. Eine operative Behandlung ist unnötig.

Von 13 schwereren Schäden — luxatio acromioclavicularis — wurden 6 konservativ behandelt mit Pelotte-Heftpflasterverband und 7 operativ. Die Arbeitsunfähigkeit betrug im Durchschnitt 45 Tage für die konservativ und 65 Tage für die operativ behandelten Fälle.

3 Patienten wurden operiert mit einem extraartikulären Eingriff mittels freier Fascientransplantation als Ersatz für das geborstene lig. coracoclaviculare (plus Metalldrahtfixation in zweien von diesen Fällen). 4 Patienten wurden operiert mittels verschiedener Eingriffe direkt am Gelenk.

Funktionell war das Resultat ein gutes in allen nachuntersuchten konservativ oder operativ behandelten Luxationen. Anatomisch war das Resultat in der Regel schlecht in al-

len konservativ behandelten Fällen und in jener Fällen wo der Eingriff direkt am Gelenk vorgenommen wurde. Ein sowohl funktionell als auch anatomisch gutes Resultat wurde registriert 5, resp. 3 und 2 Jahre nach der Operation mit freier Fascientransplantation. Die vom Verfasser in den beiden letzten operierten Fällen angewendete Methode der freien Fascientransplantation und Metalldrahtfixierung wird für die schwereren Fälle von Luxation anbefohlen, in welchen die Ligamentverbindung zwischen proc. coracoid. und clavicula vollständig zerstört ist.

Abnorme Verkalkungen im Gebiete des Schadens wurde in 14 von 17 röntgenuntersuchten Fällen festgestellt.

Die Verkalkungen treten auf gleichgültig ob der Schade leicht oder schwer war, und unabhängig von konservativer oder operativer Therapie. Man kann sie schon 3-4 Wochen nach dem Unfalle beobachten und sie können ihre definitive Form und Ausbreitung 2½ Monate nach dem Unfalle erreicht haben. Die Verkalkungen können Knochenstruktur besitzen, sie können den Raum zwischen clavicula und proc. coracoid. überbrücken, gleichgültig ob man operative oder konservative Behandlung anwendet. Das Alter der Beschädigten ist ohne nachweisbaren Einfluss auf das Auftreten der Verkalkung und diese selbst hat keinen Einfluss auf das funktionelle Endresultat.

Die Verkalkungen können sich in verschiedenen Teilen des lig. coraco-claviculare lokalisieren, bei verschiedenen Fällen in verschiedener Weise, und auch im Gebiete der articul. acromioclavicularis. Ihre Ausbreitung wechselte sehr von einem kleinen kalkdichten Fleck zu ausgebreiteten Verkalkungen an mehreren Stellen im Gebiete des Schadens.

In den mit freier Fascientransplantation behandelten Fällen zeigen die Verkalkungen immer eine knochenartige Struktur und sind in der Hauptsache im oder um das Transplantat lokalisiert.

Bezüglich der Frage eines Zusammenhanges zwischen arthrosis deformans und akuten Schäden im Acromioclaviculargelenk kann man, nach dem Material des Verfassers zu

urteilen, nicht ausschliessen, dass eine arthrosis deformans sich entwickelte oder verschlechterte auf Grund des Unfalles.

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AFFERENT PAIN PATHS IN MAN RUNNING  
FROM THE SPONGIOSA IN THE FEMORAL HEAD AND  
PASSING THROUGH THE LUMBAR SYMPATHETIC  
GANGLIA

BY

SVEN KIÆR

INTRODUCTION

Amongst the operations used in the palliative treatment of painful osteoarthritis of the hip, is the not unimportant operation of drilling of the head of the femur by *Graber Duvernay's* method. Although this treatment is regarded sceptically in many clinics, we have found that it relieves the pain for varying lengths of time in about 50 % of patients.

It has therefore, seemed desirable to discover why this operation so frequently relieves the pain. The operation itself, viz: drilling of the head and neck of the femur with a drill (6 mm. diameter) is rather surprising, if only because recent information about the pain's pathogenesis suggests that the pain originates in the joint capsule, which has a very rich somatic and automatic innervation. It is reasonable to suppose that the relief of the pain, which frequently follows blocking of the sympathetic—either by procain or by irradiation with x-rays—is due to a sympathetic effect, acting either by causing changes in the circulation, and thereby affecting the mode of response of the pain end organs, or, more hypothetically, by blocking sympathetic pain paths leading from the joint capsule.

During some introductory investigations designed to study the response to drilling of the femoral head, I have studied the pain responses both without and with sympathetic block. The findings seem to be of some interest for the question of

the pain paths in the sympathetic system. As our knowledge in this field is limited, all observations concerning it must have some value at present, though later this value may—when observations and experimental investigations have accumulated—be reduced or perhaps altogether lost.

#### PAIN PATHS IN THE SYMPATHETIC

The presence of afferent sympathetic nerve paths is an open question. It is extremely difficult to fit together the different findings. This is probably due to the fact that they have been obtained, both by experimenting in animals and by studying pain in man, and it is necessary, in studying the physiology and anatomy of the sympathetic system, to show particular reserve in comparing the results obtained in animals with those obtained in man.

As early as 1896, *Dogil* showed that there were both motor and sensory cells in the stellate ganglion in dogs. *Foerster* suggested that there must be pain fibres in sympathetic nerves, since he could still elicit pain by pinching the arteries in the arm of a young man with complete interruption of the cervical and brachial plexuses.

*Leriche*, *Tardieu*, *Fontaine* and *Foerster* believe that there are pain fibres in the perivascular plexus, and that fibres from this plexus run direct to the sympathetic chain. It should be noted that this applies only to the proximal parts of the large vessels. *Leriche* and *Tardieu* also believe that the injection of corrosive fluids into the arteries causes pain, which is abolished by sympathectomy. *Moore* and *Singleton* were, however, unable to confirm this. They believe that the sympathetic ganglia have little importance in carrying the impulses from the vessels, and that the pain is purely somatic. The difficulty of solving this question is illustrated by some experiments which *Threadgill* made on dogs. He found, from studying the effect of heat and of injections of lactic acid into the arteries, that there must be centripetal sympathetic fibres which pass through the sympathetic ganglion into the

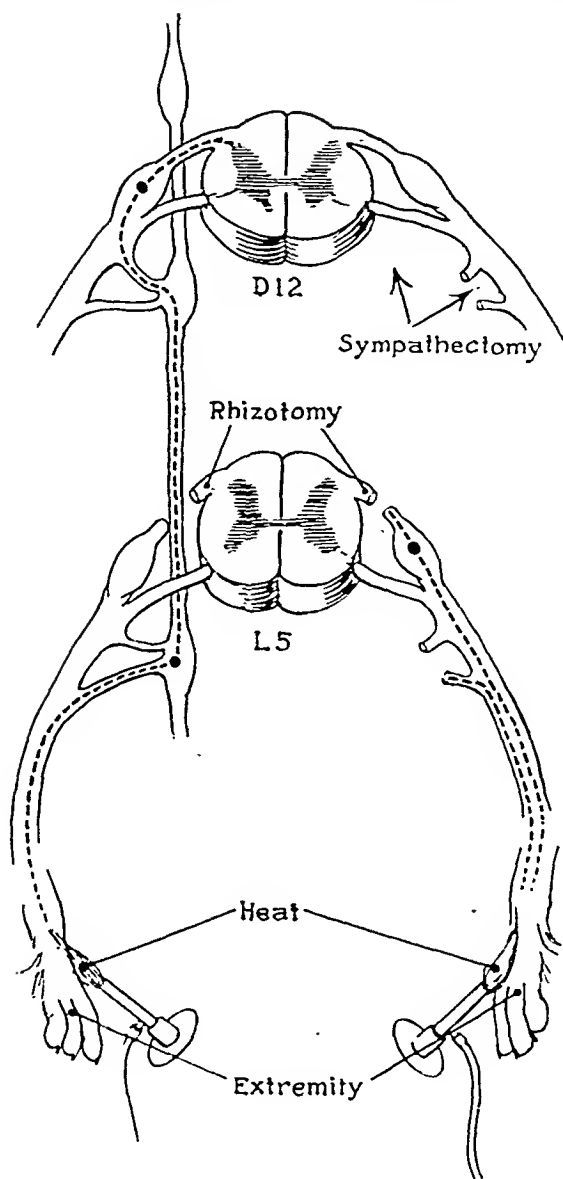


Fig. 1.

(Preparation 1).—Showing bilateral posterior rhizotomy of nerve root to leg with unilateral sympathetic ganglionectomy. Painful sensations from heat are manifested by reaction on the nonsympathectomized side only. The anterior roots are undamaged. (Threadgill. Surgery 1947.21.569).

posterior spinal nerve root and via the spinal ganglion into the posterior horn, there to release a painful sensation and perhaps a reflex response to pain (fig. 1). He also showed very nicely that when the connection with the spinal medulla



was interrupted by dividing the anterior and posterior roots, a vascular response could still be carried by the sympathetic alone, without the intervention of the spinal medulla (fig.2). These findings are very significant, but are in clear opposition to *Singleton's*.

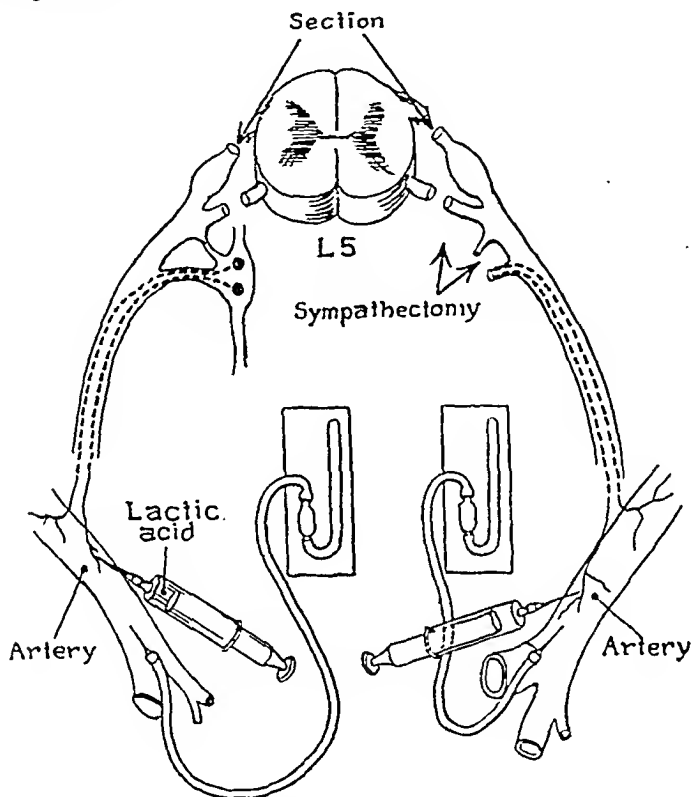


Fig. 2.

(Preparation 2).—Showing bilateral section of both anterior and posterior nerve root with unilateral sympathetic ganglionectomy. Lactic acid injection of artery of leg shows blood pressure changes on nonsympathectomized side only. (Threadgill. Surgery 1947.21.569).

Some other workers in this field, *Takats* and *Livingstone*, cannot wholly accept *Threadgill's* view.

Some interesting observations which *Arnulf* made on man should also be mentioned. Electrical stimulation of the sympathetic in man caused pain responses in certain areas corresponding to the ganglion stimulated; the pain was deep and never cutaneous. The topography varied but showed certain

main characteristics. (It is typical of sympathetic reactions that the behaviour pattern of the subject affects his responses and therefore the findings). Thus, stimulation of the left stellate ganglion provoked cardiac pain, and stimulation of both left and right stellate ganglia a deep pain in the scapular region.

When the 1st lumbar ganglion was stimulated, the pain was located in the lumbar region, the kidney area and the inguinal region. Stimulation of the ramus communicans sometimes caused a pain passing down the lower limb. After ramisection, stimulation of the 1st lumbar ganglion caused no pain. It is not clear from the paper how much the second lumbar ganglion was investigated, or whether the trunk was divided.

*Arnulf* believed that a painful sensation could be released from the first lumbar sympathetic ganglion, the sensation being felt in the lumbar and inguinal regions. Both isolation of the ganglion and spinal anaesthesia abolished the pain, and he concluded that there must be pain fibres in the sympathetic system. He further believed that the pain area is very variable and that there must be an individual determining factor.

## OBSERVATIONS

All the subjects (7) were elderly persons with painful osteoarthritis of the hip requiring palliative relief of the pain by drilling. The operations were performed under local anaesthesia (procain 1 % without adrenaline). Only the skin and muscles were injected with this solution. In 5 cases the first and second lumbar ganglia were also blocked with 2 % procain without adrenaline. In 1 case the block failed, and this case is included among the patients in whom the sympathetic was not blocked. No sensory disturbances could be detected, so one can assume that the block affected only the sympathetic. The effectiveness of the sympathetic block was confirmed in all cases by the rise in temperature. The first case was examined on 4.2.42.

During the operation the pain response of the different

bone elements was noted, and when, in the cases without sympathetic block, the pain was severe, procain was injected into the burr-hole; the injection allowed rather less than 1 cm's further drilling before the next pain response. In some cases it was necessary to use  $N_2O-O_2$  to produce general analgesia.

	Periosteum	Cortex	Spongiosa
No sympathetic block (3 cases) .....	3 +	3 ÷	3 +
Sympathetic block .....	2 ÷	4 ÷	4 +
(4 cases) .....	2 +		

Drilling of the head and neck of the femur with and without blocking of the 1st and 2nd lumbar sympathetic ganglia. Pain response ... + and ÷.

Fig. 3.

The results are shown in Table 3: In all cases without a sympathetic block there was a marked pain response when the periosteum was traumatised, and particularly when it was pulled. No pain was produced from the cortex. But severe pain arose from the spongiosa. Of the 4 cases with sympathetic block, 2 felt pain from the periosteum and 2 no pain; none of them felt pain when either the cortex or the spongiosa was bored. Thus there is a definite difference between the cases with and without sympathetic block, in that the cases with sympathetic block felt no pain from spongiosa; on the other hand there was less certainty in the case of the periosteal pain, though it should be noted that this was absent from 2 of the blocked cases.

## DISCUSSION

These observations support the view that pain paths run from the spongiosa in the femoral head to pass through the sympathetic ganglia. If these observations are regarded in the light of *Threadgill's* and *Arnulf's* investigations, it is reasonable to suggest that there are pain fibres running in the sympathetic nerves. Whether these are purely sympathetic fibres, or are somatic fibres running in the sympathetic system with the sympathetic fibres, cannot as yet be determined.

The question, from which elements in the bone is the pain released, is difficult—not to say, impossible—to answer. It is however, reasonable to believe that the pain arises in the nervous apparatus of the bone vessels; it can hardly have anything to do with changes in the vascular milieu, since it is instantaneous, which suggests a direct irritation of the pain elements.

There is, however, also another observation which is difficult to explain, namely the mechanism of the pain in osteoarthritis deformans, which is relieved by drilling. The investigations have not so far been able to explain—apart from speculatively—why boring into the spongiosa abolishes the pain in some cases of osteoarthritis deformans. It may, however, be mentioned that some of our patients with arthrosis deformans of the hip have had temporary relief from pain after procain blocking of the sympathetic.

#### SUMMARY

During drilling of the head and neck of the femur—inforatio coxae—pain occurs when the spongiosa is reached. This pain is not felt when the 1st and 2nd lumbar sympathetic ganglia have been blocked with procain.

#### ZUSAMMENFASSUNG

Während der Bohrung im collum und caput femoris entstehen keine Schmerzen, wenn das 1. und 2. lumbale Sympaticusganglion mittels Procain blockiert worden ist. Dagegen werden von der Spongiosa aus Schmerzen ausgelöst wenn die Sympaticusblokade nicht vorgenommen wurde.

#### RESUME

Lorsqu'on perfore le col et la tête du fémur (inforatio coxae), il n'est pas ressenti de douleurs si les ganglions sympathiques des 1<sup>ère</sup> et 2<sup>ème</sup> vertèbres lombaires sont bloquées à la procaine; par contre les tissus spongieux déclenchent des douleurs quand le sympathique n'a pas été bloqué.

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PERMANENCY OF RESULTS OBTAINED BY  
SYMPATHETIC SURGERY IN THE TREATMENT  
OF PHANTOM PAIN

BY

K. E. KALLIO

Ever since 1937, when *Leriche* stated that it is possible to cause phantom limb pain and often the entire phantom to disappear by sympathetic surgery, the method has been used with increasing interest. Information concerning late results obtained by this method of treatment is, however, remarkably scanty.

The few reports which I have been able to find in the literature are rather varied. So far as I can find, the largest follow-up so far published has been *Wertheimer's*. It included twenty-seven cases. Stellate infiltration in 3 cases gave a negative result in one, improvement in one and cure in one. Two stellectomies gave good results; in one of these the result was good "even after half a year". One stellectomy led to a thoracic sympathectomy, and the improvement was confirmed one and a half years later. Even after four years the result was fairly good in a case of peribrachial sympathectomy. Out of twelve cases of lumbar infiltration three gave negative results, seven improved slightly, and two led to a sympathectomy, with improvement of one. The results of perifemoral sympathectomy were good in two cases, even after 6-12 years. *White* had complete success in four out of eight cases, in which, it is true, the pain was localized in the stump, and in the remaining four the symptoms were alleviated, though only for a few months. In *Sicard's* three cases the phantom pain recurred at latest a year after lumbar sympathectomy,

but *Leclerc* had five good results from sympathectomy even after 4-10 years, and a "lasting success" in four cases treated by infiltration. However, he also had two negative results, even though the sympathetic operation was combined with resection of the peripheral nerve. *Fontaine* and *Frank* reported twelve cases of phantom pain which, with one exception, had been operated on by Leriche 8-20 years ago; in all of them the immediate results were good, but in eight the pains returned gradually. These writers consider that sympathectomy early after the amputation would give better results.

Thus, the above survey shows only twenty-four cases (*Wertheimer*, *Leclerc*, *Sicard*, *Fontaine* and *Frank*) which have been followed for at least one year. This suggests that experience concerning the treatment of these conditions by sympathetic surgery is still far too limited to enable us to evaluate its practical importance.

In order to throw some light on this matter, I have followed up 68 cases. A questionnaire was sent to all disabled soldiers who had been treated for phantom pain by sympathetic surgery in our hospital between one and four years previously. The series included fifteen cases which were reported three years ago, when the follow-up period was only two to four months (*Ellonen*). In 65 cases the pain was located in the phantom limb, and in six of these it was felt simultaneously in the stump. In the remaining three cases the pain was felt only in the stump. In all cases where the upper limb was affected stellate infiltration was first attempted several times and sympathectomy was not performed if novocaine had no effect. In the beginning the same procedure was also used in cases where the lower limb was affected. In the upper limb cases, which were all operated upon by myself, a stellectomy of the classical type, with removal of the first thoracic ganglion, was performed, except in the first two operations, which were less radical. At lumbar sympathectomy usually the two lower lumbar ganglia were removed.

There were twenty upper limb cases; in fourteen the upper arm and in six the fore-arm was concerned. In thirteen the

treatment had no effect, not even temporarily. In one, the pain moved from the phantom limb to the stump. In four the relief of the phantom limb pain after sympathectomy lasted for only a few weeks, and in another case a good result after infiltration ended in recurrence after half a year. On the other hand, one patient reported three years after the operation that the phantom pain had continued to be milder, and one reports that he is still perfectly well. In this case a stellectomy had been done four years after the amputation. The pain as well as the phantom disappeared immediately after operation and are still absent after one and a half years. In this connection I should like to report another stellectomy with a successful result which I performed 6 months ago.

There were seventeen cases of thigh amputation. 16 suffered from phantom limb pain alone and one also from pain in the stump. Lumbar sympathectomy was done in fourteen cases. In six, of which three had only an infiltration, there was no improvement. In nine all pain, and in three also the whole phantom limb, disappeared after the operation, but the improvement lasted only 3-30 days. In some cases both the pain and the phantom disappeared for 18 months and then recurred in a still worse form. In two cases of phantom pain treated by sympathectomy the result was perfect three years and three months respectively after the operation: both pain and the phantom limb had disappeared, and this favourable result is still lasting after three years.

There were thirty cases of pain following below-knee amputations. The pain was located in the phantom in twenty-six, in the stump in two, and in both the phantom and the stump in two. Lumbar sympathectomy was done in twenty. In ten the operation did not even give passing relief; on the contrary, it made the pain worse. Previously, attempts had been made to treat the persistent pain by removing the neuroma; in one case the removal of the neuroma was, as recommended by *Fontaine*, performed at the same time as the sympathectomy. In ten cases the pain disappeared and even the phantom limb disappeared completely in three, and parti-



ally in another three. Unfortunately the condition recurred in five cases within 6 months and in three cases after 1-2 years. Only two said that they were completely cured, but not more than a year had elapsed since the operation. In addition, there was one patient who recovered after two novocaine infiltrations: the pain disappeared completely and left behind the phantom limb. This result, so easily obtained, has lasted for four years. This was the only positive result in ten cases treated by infiltration. There was one case of foot amputation, in which neither the pain in the stump nor that in the phantom foot improved after sympathectomy.

Thus in the majority of cases (39 out of 68) sympathetic surgery did not cause even temporary relief, and in one case it even made the pain worse. Yet the surgeon who treated these cases had at first favourable impression of the results because in a large proportion of the cases (29 out of 68) the immediate results were quite good. An adequate follow-up, however, was disillusioning: the successes proved to be only temporary (21 out of 29) and in most cases lasted only a very short time, usually six months or less (16 out of 21). In five cases the pain was absent for 1-2½ years. It is probable that even in the best cases of my series, i.e., where treatment resulted in complete cure, the end results will be less favourable than expected. Although in three of these patients the improvement has been maintained for 3-4 years, the observation time of the others has been only 1-1½ years. The fifteen cases of this series who were reported by *Ellonen* provide an excellent illustration of how easy it is to overestimate the value of sympathetic surgery in treatment of phantom pain when the observation time is too short. *Ellonen* stated after an observation time of 2-4 months that the pain had disappeared completely in seven and was relieved in two cases, but now only one of these patients is still satisfied with the result.

The results did not seem to depend on the length of the interval between amputation and sympathetic surgery, as maintained by *Fontaine* and *Frank*. The operation was com-

pletely successful in four cases treated as late as 3-5 years after the loss of the limb, while on the other hand, it was quite ineffective in some cases treated only one month after the amputation.

The sympathetic operations used may be discussed here. Though, in practice, stellectomy has been considered the method of choice, the anatomy suggests that removal of the second and third thoracic ganglia (*White*) might have given more positive results. Likewise, it might have been advisable to include higher lumbar ganglia at lumbar sympathectomy. However, though the number of each positive results might have been increased, it is doubtful whether there would have been any improvement in the end results. Besides, there is a great deal of evidence that in these cases success does not generally depend on the extent of the sympathetic resection (*Wertheimer, Leclerc, Fontaine and Frank*).

To sum up, I should like to say that, in the treatment of phantom limb pain, sympathetic surgery fails in a large proportion of cases to yield the desired result, and that in the numerous cases where the immediate result is favourable pain often recurs even as early as 1-4 years after the operation.

## SUMMARY

The subject referred to in the title of this article has been little studied so far. The present writer followed up 68 cases, including 8 stellectomies, 34 lumbar sympathectomies, and 26 infiltrations. In the majority of the cases (39) sympathetic surgery was found to have no effect, and in one case it made the pain worse. In 29 cases the immediate results were good, but after 1-4 years only 6 patients reported that they were completely cured, and one said that the pain was less severe than before. The writer finds that the value of sympathetic surgery in the treatment of phantom limb pain has been overestimated.

## RESUME

Le sujet indiqué par le titre de cet article a été très peu étudié jusqu'ici. L'auteur a suivi 68 cas, comprenant 8 stellectomies, 34 sympathectomies lombaires et 26 infiltrations. Dans la majorité des cas (39) la chirurgie sympathique n'a produit aucun effet et dans un cas les douleurs ont été même aggravées. Dans 29 cas les résultats immédiats ont été bons, mais au bout d'une durée variant entre 1 et 4 ans, 6 malades seulement ont été signalés comme entièrement guéris et l'un déclarait que les douleurs étaient moins fortes qu'auparavant. L'auteur trouve que la valeur de la chirurgie sympathique dans le traitement du fantôme douloureux a été surestimée.

## ZUSAMMENFASSUNG

Der Frage, die in dieser Arbeit untersucht wurde, ist bisher wenig Aufmerksamkeit geschenkt worden. Der Verfasser hat 68 Fälle nachuntersucht, die 8 Ganglion stellatum Exstirpationen, 34 lumbale Sympatektomien und 26 Sympatikus Infiltrationen umfassen. In der Mehrheit der Fälle (39) war Sympatikus Chirurgie wirkungslos und in einem Fall nahmen die Schmerzen nach der Operation zu. In 29 Fällen war der unmittelbare Erfolg gut, aber nach 1—4 Jahren erwiesen sich nur 6 Patienten als vollständig geheilt, und ein Patient sagte, dass seine Schmerzen weniger ausgesprochen als vor der operation waren. Der Autor findet, dass der Wert der Sympatikus Chirurgie in der Behandlung von Phantomschmerzen der Extremiteten überschätzt worden ist.

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## TETANUS PROPHYLAXIS FOR ORTHOPAEDIC OPERATIONS

BY

IVAR BORG

Most of the postoperative cases of tetanus described in the literature have followed: gynaecological operations, such as criminal and legal abortions, operations for salpingitis and hysterectomies; intestinal operations, such as appendicectomies; and tooth extractions and other operations in the oral cavity and pharynx. A large number of single cases of tetanus have also been reported after almost every kind of operation. At the beginning of the twentieth century tetanus neonatorum was a common, and rightly feared, disease; in Hungary as many as 10,000 deaths from this disease have been reported during one year (1904). At one period "the eight days sickness" on the island of St. Kilda carried off two-thirds of all newborn infants. That the mortality was heavy is evident from the name, which indicates the short period of incubation. This form of tetanus has now practically disappeared, and is scarcely ever seen in our hospitals.

Orthopaedic operations may also be followed by tetanus, especially operations on the lower limbs, more particularly the feet.

*Satta* (1924) reported three cases of tetanus occurring after operations on the foot. In the first two, tetanus followed resection of the calcaneus, and contamination of the skin was considered to be the probable source of infection. *Strebel* (1927) described a case which developed tetanus 5 days after an aseptic operation for pes cavus, and died within 14 hours. He considered skin infection to be the cause, and prophylactic serum treatment was afterwards introduced at similar operations. *Königswieser* (1929) published three cases of tetanus following aseptic operations on

the foot, occurring in a period of 5 years at the Orthopaedic Hospital of Vienna. Two of these followed arthrodesis of the ankle for sequelae of poliomyelitis. In both cases there was secondary infection, and tetanus developed on the 8th and 12th days, leading to death within 4 days and 12 hours respectively. The third case developed tetanus on the 6th day after an operation for talipes cavus by Spitzzy's technique, and died within 24 hours. Autopsy showed "discoloration of the wound", which otherwise had a normal appearance. As these cases were published, efforts to perfect asepsis were increased: sterile plaster, no insertion of osteosynthetic material direct through the plantar surface, a separate knife for skin incisions, and, finally, prophylactic serum treatment were introduced for all bigger foot operations, especially those in which the incision was made on the plantar surface. *Edelman* (1931) reported a case of tetanus 10 days after the application of a calcaneus extension for fractured leg. Since then, he has used serum prophylaxis with all foot operations or foot tractions, and considers this well advised, in spite of complications of serum treatment. *Karl Schnaberth* (1941) described two cases of tetanus in the Orthopaedic Hospital of Vienna. In one, tetanus developed on the 12th day after a Chopart's amputation for deformity from a traumatic paresis; 6 days later the patient had recovered. In this case the splint had also caused a bad pressure sore on the foot, whose skin was susceptible as a result of the nerve injury. The second case followed a club-foot operation on a foot with pronounced cavus formation from the use of an orthopaedic splint. Secondary infection arose, and on the 12th day tetanus developed. The patient recovered. *Schnaberth* stresses the importance of changes in the skin caused by splints in these cases. *Gordh* (1945) described a fatal case of tetanus developing 5 days after an operation for hallux valgus on a patient with a coarse and rough skin. Other cases of tetanus after aseptic surgical measures on the foot are reported. *Manelaira* (1932) had 3 cases of tetanus after operations for club-foot, *Kaufman* (1932) a similar case, *Waterman* (1933) a case after operation for talipes cavus, and *Clarenz* (1935) 2 cases following operations on the foot.

Probably some of the cases published in the literature as "Spättetanus" can be explained on the same basis. By "Spättetanus" is meant the development of tetanus from material which was introduced at an earlier injury but remained latent and was able to develop in the favourable conditions after a later operation. *Lange* (1942) describes as "Spättetanus" one case which exhibits a certain amount of parallelism with those described above. The patient received at the same time as a foot injury with fracture-luxation, also a "small wound" over the medial malleolus which healed without complication. After a later operation to correct the deformity, tetanus developed on the 16th day; splitting the plaster revealed a reddened, partly moist area in the field of operation.

The patient was discharged healthy. It would seem most probable that the infection had arisen at the operation, and that only in the favourable soil afforded them later on were the bacteria able to emit their toxin. The "small wound" connected with the primary injury need not be invoked as the port of entry, and the term "Spättetanus" does not appear to be appropriate in this case.

At the Orthopaedic Department of the Central Hospital, Örebro, we have recently had a case of tetanus following a foot operation:

A 52-year old workshop turner, Jnl. No. 48/48; A subtalus arthrodesis was made on his right foot for pes varus paralyticus post poliomyelitis. After the operation a foot plaster was applied. During the next few days penicillin was given prophylactically, and the patient was allowed up on the 8th day, and to leave the hospital 11 days after the operation without signs of infection.

23 days after the operation the patient had cramp in his neck and difficulty in opening his mouth. These increased, and after 3 days he had to stay in bed. On the 4th day he was sent in to the hospital with the diagnosis of tetanus. After discharge he had not had any accident, and had not injured himself, been bitten, or had any wounds or sores. On admission, 27 days after operation, he complained of pain in the nape of his neck so that he could hardly move his head. He could only open his mouth to give 1 cm between his front teeth, and then there was a painful spasm of the masseters.

When the plaster was split, necrosis of the wound, such as is often seen after these operations, was found; the wound was re-excised. Later, episthotonus and contraction of the abdominal muscles developed. He was treated with large serum doses, sedatives, and penicillin and, without any definite spasms, the condition gradually subsided, and on the 17th day he was discharged free from tetanus. The only complication was a moderate serum urticaria, which appeared on the 9th day after admission, and quickly vanished under treatment with calcium, ephedrine and Antasthen.

There was no reason to suspect defective sterility of the surgical instruments, catgut, towels or bandages, as neither before nor since has any other case of postoperative tetanus occurred in this theatre, which has been used by the surgeons of the hospital for many years.

Most probably the wound was infected by tetanus bacteria

or spores on, or in, the skin; these can never be entirely eliminated by skin-disinfecting measures. Tetanus spores may remain in sweat and sebaceous glands, and in fissures, particularly those present in thick skin, they may "heal into" the horny layer and remain latent for a long time. The skin on the sole of the foot is often a half centimetre or more thick, and frequently cracks, especially if there is a deformity of the foot and cutaneous changes have developed from mechanical conditions such as pressure from shoes or splints. In these cases it is impossible to ensure perfect sterility of the skin. In addition, the lower limbs, and particularly the feet, are also most exposed to contamination.

Case histories from the literature show that tetanus is more common after wounds on the feet and legs than after wounds on other parts of the body. *Vinnard* states that of 269 cases of traumatic tetanus, 205 were caused by injuries of the lower limbs. *v. Bakay* and *v. Klimko* attribute 76 % of the cases to lesions on the lower extremities, and 71 % of these to wounds confined to the feet. The predominance of the foot as infective focus is still more notable when it is recalled that the feet (and toes) constitute only 3,6 % of the whole body.

In our case, both the long time between the operation and the tetanus, 23 days, and the benign course favour the view that the tetanus bacteria or spores from the skin had been deposited in the wound at the operation and that they were only able to develop gradually when the necrotic tissue and secondary infection were established. Certainly, a later contamination should have produced a more serious form of the disease.

A further factor of importance in the occurrence of tetanus in our case is that skin-necroses and secondary infections in the field of operation frequently occur after subtalar arthrodesis, and, as a result, conditions are often favourable to the development of anaerobic bacteria. In addition, relatively short decubitus is part of the treatment, and tetanus material can enter secondarily through the plaster dressing which is opened in front when the patients are about on their feet.



The cases of postoperative tetanus described in the literature often had a very severe course, with a short latent period and high mortality, as has been shown by the case histories already described. The average mortality for all tetanus cases ranges from 45 to 70 % in the larger series, though it was lower—30 %—in recent smaller series. Among *Vinnard's* 352 cases of tetanus, 11 followed surgery. The operations were: 5 tooth extractions, an appendicectomy, a herniotomy, a hysterectomy, a jaw operation, a ganglion operation and a subcutaneous injection. 6 of the patients died. *Bunch* and *Quattlebaum* reported 8 cases, 6 following gynecological operations, with 7 deaths. *Schmid* reports 9 cases following intestinal operations, with 9 deaths; 25 following gynecological operations, with 17 deaths; 11 following hydrocele-hernia operations, with 8 deaths. This high mortality may have been due to a more massive infection, or to the patients' lowered resistance due either to the primary disease or to the operation, and also to the difficulty of diagnosing mild cases. It is not possible to obtain a true figure for the frequency of tetanus following operation in modern hospitals, since milder cases will often escape diagnosis. When tetanus appears late, its symptoms are usually slight, and are probably not always recorded. Further, the surgeon's disinclination to report its occurrence may also make it difficult to assess the frequency. However, tetanus is probably not a common complication of operation, though when it occurs it is an extremely unpleasant one.

The present case stresses the need to try in every way to avoid tetanus as a postoperative complication. It is impossible to set up rules for the general preoperative prophylaxis of tetanus, but within orthopaedics there is a group of patients, represented by our own case, which is well suited to such treatment. Corrective treatment of deformities of the feet and legs (either for deformities or posttraumatic conditions) frequently cause more or less extensive skin necroses, with secondary infections which have developed during prolonged plaster treatment, and afford favourable conditions for the tetanus bacteria introduced into the operation wound from the skin to exercise their toxic action. These typical chronic cases have the advantage that they need not be operated immediately, so that the tetanus prophylaxis which is most effective and has fewest complications, viz. immunisation with tetanus anatoxin, can be given pre-operatively. The papers quoted above show that, in the past, orthopaedic surgeons have not withheld serum

treatment from cases requiring operations on the feet, in spite of its great disadvantages (inadequacy, serum sickness and anaphylaxis, with, not rarely, death). Now that a vaccine is available there is still less reason for withholding tetanus prophylaxis. Experience has shown that vaccine gives a safe and very effective prophylaxis.

At the Orthopaedic Department in Örebro we now give tetanus vaccine to those of our patients who have operations on the feet or legs. At their first visit they receive 1 ml. of vaccine, after 4 weeks 2 ml., and after 8 days another 2 ml., and we consider that these precautions give a satisfactory degree of increased safety.

#### SUMMARY

A case of tetanus following an operation on the foot is reported, and routine prophylactic vaccination before operations on the lower limbs, particularly the feet, is recommended.

#### RESUME

Il est rapporté un cas tétanos dans le pied, suivi d'une opération. La vaccination prophylactique ordinaire de l'extrémité inférieure et particulièrement du pied est recommandée avant l'opération.

#### ZUSAMMENFASSUNG

Ein fall von Tetanus im Gefolge einer Operation am Fusse wird berichtet und rutinemæssige prophylaktische Vakzination vor Operationen an den unteren Extremiteten, besonders an den Füßen, wird empfohlen.

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ACTIVE TENODESIS, AN ATTEMPT TO  
CORRECT PARALYTIC DROP-FOOT WHILE  
PRESERVING THE MOBILITY

BY

L. E. LAURENT

The treatment of paralytic drop-foot varies according to the extent of the paralysis.

1. *All muscles of the foot and lower leg are paralysed.*

Various stabilizing operations have been suggested: astragalectomy, tendon fixation (*Gallie*), panastragalar arthrodesis, posterior bone-block, and wedge subastragalar arthrodesis (*Lambrinudi*). Appliances may be used for children too young for arthrodesis, and for patients unwilling to have an operation.

2. *Three or two muscles have good power.*

When there are three strong muscles, one of them is transplanted to the calcaneus, and one to each side of the foot; this is often combined with subastragalar arthrodesis. When there are two good muscles, one of them is transplanted to the calcaneus and one to the middle of the dorsum pedis and subastragalar arthrodesis is necessary.

3. *Only one muscle is active, usually the triceps surae.*

Either an appliance or one of the operations used for total paralysis may be chosen. Panastragalar arthrodesis is not suitable. Good results may be obtained by a subastragalar arthrodesis combined with posterior arthrorisis, or by a Lam-

brinudi subastragalar arthrodesis, but these methods considerably reduce both active and passive flexion and, for instance, the use of an ordinary riding-boot is prevented. In order to preserve this valuable mobility, a method, which is termed active tenodesis, has been tried at the Orthopaedic Hospital of the Invalid Foundation at Helsingfors. It aims to preserve passive movement at the ankle joint and to enable the patient to keep the foot in a neutral position by the active contraction of the triceps surae.

*Method:* Through anterior and lateral incisions the tendons of the paralysed tibialis anterior and peroneus brevis are divided where they join the muscular tissue. Through a small incision at its distal insertion the peroneal tendon is pulled out and passed up via the lateral tendon sheath of the extensor dig. comm. to the anterior incision. If the tendon of peroneus brevis is too weak or too short, that of the peroneus longus can be used, attached by a silk suture to the distal insertion of the peroneus brevis. A hole is cut in the interosseous membrane, and both the tendons are passed through it to the lateral incision, where with the foot in maximum dorsiflexion, the tendons are passed through the tendo Achilles and attached to it with silk suture. The tendo Achilles should be lengthened, if it is contracted. In some cases the tendon fixation has been combined with ordinary subastragalar arthrodesis.

In 1902, *Vulpinus* described a method in which the active tendo Achilles was split into three parts. One lateral part was joined to the tendon of the tibialis anterior, and the other to the tendons of peroneus longus and brevis. *Vulpinus* expected the different parts to function separately, but this did not happen, and the procedure was ineffective.

*Haglund*, in 1913, described a method of tendon fixation in paralytic drop-foot, which he termed "activated tenodesis". He attached the tendons of the paralysed tibialis anterior and ext. dig. communis to the tibia. If there was some contractile muscle present, the tendons were divided above the suture, and the proximal and distal ends of the tendons were joined distal to the tenodesis. By this means he hoped to be able to utilize any existing muscle power. However, if a muscle retains part of its contractile power, it should be possible to utilize it in other

ways than by this kind of tenodesis, whose effect is small if there is severe paralysis.

The active tenodesis, which has been tried at the Invalid Foundation has not, I believe, been described before in the literature.

Failures must be expected, as the tendons may become attached to the interosseous membrane or to the bone; the tendons may stretch on one or both sides; or the tendon suture may break.

6 patients have been treated by this method and have been observed for from one to three years. In 3 the tendon fixation was combined with subastragalar arthrodesis. 5 had had infantile paralysis, and 1 a myelitis of unknown etiology which had caused paralysis of all the long muscles of the foot, excepting the triceps surae. The operation has also been done on 5 further patients, but the time of observation is less than one year.

Of the 3 cases treated by tenodesis alone, 1 showed a good result. At follow-up examination there was almost full passive dorsal and plantar flexion of the foot. Contraction of the triceps surae pulled the foot into slight plantar flexion, regardless of its initial position. In the other two patients the equinus position was increased, and there was a tendency to varus position due to stretching of the transplanted tendons. These relapses were corrected by shortening the tendons. A small incision was made on the dorsum of the foot under local anaesthesia. By shortening one tendon more than the other, any varus or valgus position of the foot can be corrected. Of the 3 cases in which tenodesis was combined with subastragalar arthrodesis, 2 showed a satisfactory shape and position of the foot at the follow-up examination. Passive dorsal flexion was full; there was active plantar flexion to about  $120^\circ$ ; and a little more passive plantar flexion. There was, however, no active dorsal flexion by the triceps surae. Probably the transplanted tendons had become adherent to the interosseous membrane. The third case had a less good result; it had relapsed due to stretching of the tendons.

Thus, this method may give satisfactory results, but it is not reliable. Tenodesis alone does not prevent other operations being performed later, and this is one of the advantages of the method. When it is combined with subastragalar arthrodesis, stability of the subtalar joint is obtained. However, arthrodesis requires a long period of immobility and there is a great risk that the transplanted tendons will become adherent to the interosseous membrane or to the bone with loss of the active

function. For children, whose splints have to be renewed frequently and in whom the active muscle should be used to prevent atrophy, the method is suitable until they are old enough for arthrodesis. Should tenodesis prove unsatisfactory, another stabilizing operation may be done later. A Lambrinudi arthrodesis, or posterior arthrorisis may be performed first, and, if the result is unsatisfactory, panastragalar arthrodesis later. Several surgeons have obtained good results with arthrorisis (*Campbell, Wagner, Gill*). It is, however, difficult to perform and uncertain in its results and it may cause pain through irritation of the talocrural joint. *Lambrinudi's* operation is simpler, and, according to *Fitzgerald* and *Seddon*, the results are good, but are not always satisfactory, as instability of the talocrural joint develops later in some cases. The two methods mentioned above do not prevent recurrences due to stretching of the ligaments of the anterior joints of the foot (Lisfranc' joint and the cuneonavicular joint) and consequent recurrence of the equinus position of the anterior part of the foot. Active tenodesis prevents these recurrences as the tendon of the tibialis anterior is inserted into the first cuneiform and base of the first metatarsal, and that of the peroneus brevis into the base of the fifth metatarsal.

#### S U M M A R Y

The author describes a method, which he calls active tenodesis, for treating paralytic drop-foot. The operation aims to prevent the drop-foot while preserving the movement at the talocrural joint. The tendons of the paralysed tibialis anterior and of one of the paralysed peronei are utilized. They are divided where they join the muscular tissue: the peroneus tendon is pulled out near its insertion and passed through to the anterior side of the ankle. Both tendons are now passed through an opening in the interosseous membrane and sutured to the active tendo Achilles. The method may give satisfactory results but it is not reliable. The various treatments of paralytic drop-foot are discussed.

## R É S U M É

L'auteur décrit une méthode qu'il appelle ténodèse active pour le traitement du "drop-foot" paralytique. L'opération tend à empêcher le "drop-foot" en maintenant la mobilité de l'articulation talocrurale. Les tendons du tibial antérieur et de l'un des péroniers sont utilisés. Ils sont divisés à l'endroit où ils rejoignent le tissu musculaire: le tendon du péronier est sorti à proximité de son insertion et passé à travers sur le côté antérieur de la cheville. Les deux tendons sont passés à travers une ouverture dans la membrane interosseuse et suturés au tendon d'Achille actif. Cette méthode donne des résultats satisfaisants mais n'est pas absolument sûre. Les divers traitements du "drop-foot" paralytique sont discutés.

## Z U S A M M E N F A S S U N G

Der Verfasser beschreibt eine Methode, die er als aktive Tenodese bezeichnet, und in der Behandlung des Lähmungspitzfusses verwendet. Die Operation hat zur Aufgabe den Spitzfuss einerseits zu verhindern, andererseits aber die Beweglichkeit im Talocruralgelenk zu bewahren. Zur Verwendung gelangen die Sehnen des gelähmten tibialis anterior und eine der Peronäussehnen. Diese werden am Übergange zum Muskel-fleische durchtrennt. Die Peronäussehne wird nahe ihrer Insertion herausgezogen und zur Vorderseite des Knöchels tunneliert. Beide Sehnen werden dann durch eine Öffnung in der interosseus Membran gezogen und an die aktive Achillessehne genäht. Die Methode kann zufriedenstellende Resultate geben, aber sie ist nicht sicher. Die verschiedenen Behandlungsmethoden des paralytischen Spitzfusses werden besprochen.

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## A CASE OF SYNOSTOSIS IN THE DISTAL RADIO-ULNAR JOINT

BY

MAC FELLÄNDER

Union of the two bones of the forearm is a recognized congenital deformity, but it is rare. According to some 200 published cases the synostosis occurs invariably at the proximal radio-ulnar joint, though in a few cases the distal joint may also be affected, but usually in these cases the bones are also generally malformed. *Jemma* says that he could not find any case in the literature in which only the distal joint was involved, but he himself described a case in which the whole arm was deformed and shortened by union of the ulna and radius above the wrist. Synostosis may also occur after an arthritis which has led to ankylosis and gradual formation of a bone bridge. In infections of the joints, ankylosis generally includes both the radio-ulnar joints and the adjacent joints of the elbow or wrist.

In the case described here there was synostosis of the distal radio-ulnar joint, without any other change or deformity of the bones of the limb. I have been unable to find any similar case in the literature.

The patient is a female professional pianist, aged 38, who, in February 1948, sought advice for inability to rotate the left forearm. The hand was held in mid-position between pronation and supination and there was no rotation. Movements of the wrist and fingers on the other hand were quite normal. Radiography showed synostosis at the distal radio-ulnar joint (Fig. 1); the proximal joint was normal. At first sight the picture suggests a congenital synostosis. The outlines are regular and there is no evidence of an earlier pathological process. The history, however, excludes a congenital origin. The patient states definitely that she had



*Fig. 1.*

Radiograph before and after operation.

previously been able to rotate the forearm, particularly when playing the piano. The limitation developed in 1935, i.e. 12 years earlier, after a high fever with acute onset accompanied by severe tenderness, swelling and a bluish-red discoloration of the left wrist. At the same time she had milder pains in the other joints. The high fever lasted for 10 days and was followed by mild fever for about 10 weeks. After immobilization the wrist became stiff. Subsequent x-ray treatment gradually improved the movements, but without any improvement in rotation. These reports were obtained from a hospital for rheumatism, to which the patient was admitted one year after the acute onset. The diagnosis there was polyarthritis rheumatica chronica. The joint involvement was then reported to be mild, but the S. R. varied between 40 and 60 mm. There was no rotation of the left forearm, and radiography showed synostosis of the distal radio-ulnar joint. Re-examination of the pictures showed that the bony connection was then less compact than now.

With regard to the pathogenesis, it would seem improbable that polyarthritis can produce ankylosis of this joint with retention of normal movement in the wrist. *Payr* writes, in his book "Gelenksteifen und Gelenkplastik", that the radio-ulnar joint with its loose capsule, its



Fig. 2.

Pictures showing pronation and supination after operation.

unique structure, and its independence from the radio-carpal joint, is rarely the site of ankylosis, and that when it does ankylose the radio-carpal joint is also involved. Further, polyarthrititis is unlikely to give rise to ankylosis in so short a time. The description of the illness suggests that the condition was septic or, more exactly, a septic metastatic focus, which might conceivably have healed with resultant bony ankylosis in a relatively short time. Gonorrheal arthritis has a strong tendency to ankylosis, but it probably never occurs alone in this small joint. On the whole, it is remarkable that a serious infection could be confined to the radio-ulnar joint, which is so intimately connected with the radio-carpal joint. However, they are separated by the discus articularis, a triangular ligament with its base attached to the radius and its apex to the processus styloidei ulnae. According to text-books of anatomy there is sometimes a narrow fissure in the disc near its attachment to the radius connecting the two joints, but this connection is not general. *Patriek* studied the radio-ulnar joint by arthrography and found that the contrast medium only entered the radio-carpal joint in cases with fractures in this region, and in these cases the disc had been torn.

In discussing the treatment of radio-ulnar synostosis one should perhaps caution against intervention in patients in most occupations. As already described above, the position of the hand between pronation and supination was satisfactory. This case, however, was a pianist, who intended to train further as a professional. She compensated the loss of rotation by rotation and abduction at the shoulder-joint; this enabled her to get her fingers down onto the keys, but it was a tiring and ugly position. Arthroplasty of this small joint must be considered to be

hopeless. For painful and limited rotation after fractures of the radius, resection of the distal part of the ulna may give good results, and this was the method we used in this case. The operation offered no technical difficulties. The bone was excised and the synostosis was chiselled through without opening the wrist. The disc and capitulum ulnae were quite adherent. Normally, a small cartilage-covered area is found, i.e. a joint where the disc glides transversely on the capitulum during pronation and supination. Adhesions preventing these movements may also occur after fractures. Local anaesthesia was administered, and after resection the arm could be passively pronated and supinated to the fullest extent. Movements, first passive, later active, were begun on the day after operation. The movements of the fingers and wrists soon became normal, and on the 15th day the patient was able to resume her piano-playing. The power of pronation and supination improved rapidly, although this movement had been lost for 12 years.

The patient was re-examined 6 months after the operation; she was quite recovered, and was able to carry on her profession without disability. The movements of the wrist and fingers, and supination were normal; pronation was slightly limited. The cosmetic result was also excellent. The ulnar defect was scarcely noticeable (Fig. 2).

### SUMMARY

A case with isolated synostosis of the distal radio-ulnar joint, probably caused by a septic metastatic focus is described. It was successfully treated by resection of the distal end of the ulna.

### RESUME

Description d'un cas avec synostose isolée de l'articulation radio-ulnaire distale, probablement causée par un foyer métastatique. Ce cas est traité avec succès par la résection de l'extrémité distale du cubitus.

### ZUSAMMENFASSUNG

Ein Fall von isolierter Synostose des distalen radioulnar Gelenkes, wahrscheinlich herangerufen durch einen septisch-metastatischen Herd, wird beschrieben. Sie wurde mittels Resektion des distalen Endes der Ulna erfolgreich behandelt.

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## A SIMPLE AND CLEANLY METHOD FOR IMMOBILIZING THE WRIST

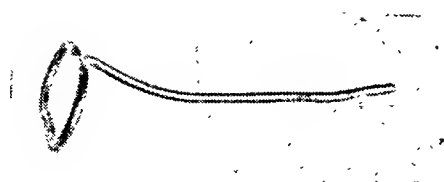
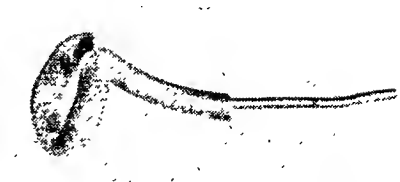
BY

IVAR ALVIK

An ordinary plaster-of-Paris cast is quite suitable for prolonged immobilization of the wrist, provided the patient is not allowed to work with his hand. With most injuries requiring such immobilization, however, it is usually necessary to allow for some movements of the hand, for ordinary work. The distal end of the plaster is therefore very liable to be damaged, softened and soiled, and if it has to support the palm for a considerable time, it needs to be so thick that flexion of the fingers is difficult. Further, abscesses and sinuses of the hand or wrist may require openings or "windows" in the plaster which not only weaken it, but also make it difficult to keep either the plaster or the skin round the wound clean and the risk of secondary infection is increased.

In such cases a plaster-of-Paris cast may be replaced by special removable splints, which are expensive.

A simple and cheap splint, which serves the same purpose, is shown in figs. 1-3. The materials needed are a stiff iron rod 5-6 mm in circumference, a rubber tube, a plaster-of-Paris bandage, and a couple of forceps for bending and moulding the rod, which must be as stiff and inelastic as possible in order to prevent the splint from bending or breaking. One end of the rod is bent to form a stirrup a little larger than the transverse section of the hand just distal to the middle of the four ulnar metacarpal bones, and its shape is adapted to that of the hand at this level, with due reference to the

*Fig. 1.**Fig. 2.**Fig. 3.*

palmar curve. The rest of the rod lies over the dorsum of the hand and the lower forearm, and is moulded so that the hand is held in slight dorsi-flexion. Before closing the stirrup the rubber tube is drawn over the iron rod to a point a little above the wrist, just high enough to be included in the plaster bandage. The stirrup is now closed as far as possible and is moulded exactly to the hand so as to immobilise it without exerting too great pressure on it. A thin tongue of plaster-of-Paris is inserted between the skin and the rod above the wrist, and a similar tongue is secured outside it. The plaster-of-Paris is then applied outside the rod so as to hold the wrist, and is moulded carefully round the distal parts of ulna and radius so that it cannot slip down: there are also several indentations on the upper part of the rod to prevent the plaster slipping. With this arrangement it is possible to wash and attend to the whole of the hand distal to the plaster-of-Paris, and sinuses and abscesses can be dressed. The wrist



is immobilized but complete freedom of movement of all the fingers and the first metacarpal is retained. This is a matter of great importance to the function of the hand. As the splint is not so thick over the palm as an ordinary plaster-of-Paris cast, maximum flexion of the four ulnar fingers is also assured. This splint cannot be used if the first metacarpal must also be immobilized.

### RESUME

L'auteur parle d'une simple petite éclisse pour remplacer le bandage ordinaire de plâtre du poignet. L'éclisse peut être mise en place par l'opérateur et consiste en un gros fil de fer recouvert d'un épais tuyau de caoutchouc plâtré dans un bandage qui ne va que jusqu'au poignet. La main et le poignet étant dégagés, peuvent être lavés et les plaies éventuelles ou les fistules soignées comme d'ordinaire.

### ZUSAMMENFASSUNG

Der Verfasser empfiehlt eine einfache, reinliche Handgelenksschiene zum Gebrauch anstatt der üblichen Gipsbandage. Die Schiene kann vom Operateur angefertigt werden und besteht aus einem dicken Stahldraht bekleidet mit einem dicken Gummirohr, das in die Gipsbandage, die nur bis zum Handgelenk reicht, eingegipst wird. Die Hand und Handgelenksregion kann auf diese Weise reingehalten werden und eventuelle Fisteln oder Wunden können in der gewöhnlichen Weise behandelt werden.

## STUDIES IN OSTEOGENESIS

BY

H. WILLESTAEDT, G. LEVANDER and L. HULT

*Levander* showed that when cell-free alcoholic extracts of bone are injected into rabbits' muscles, cartilage and bone form at the site of the injection. This finding has since been confirmed by *Annersten*, *Bertelsen*, and *Lacroix*. As extracting agents, *Levander* used both ordinary and acidified alcohol. *Annersten*, who extracted mainly with acidified alcohol, was able to show that the active factor could be transferred from alcohol to ether, benzene and oil. He used mostly homozyotic material (rabbit), but also obtained positive results in some series with heterozyotic material (calf-rabbit). *Bertelsen* tried extracts of each of the various layers of bone—periosteum, hard bone, epiphyses and marrow—and found osteogenic activity in all: the extracts from bone marrow gave the best results. *Annersten* believed that the active factor belonged to the lipid or sterol groups, in view of its solubility in benzene and oil. *Bertelsen* disagreed. Finally, *Blum* observed bone formation in rabbit muscle "in a few cases" after the injection of extracts prepared by Robinson's method for the preparation of phosphatase.

*Levander* found no cartilage or bone formation in 80 control tests in which he had used injections of pure alcohol and of extracts of connective tissue or muscle. *Annersten* found cartilage formation in 4 out of 102 control tests. Statistical treatment of his material shows, however, that "die mit Knochenextrakt erhaltenen positiven Resultate müssen einem in diesem extrakt vorhandenen Faktor zugeschrieben werden,

der in den Kontroll-experimente fehlt". *Bertelsen* found 1 positive result in 41 control tests. *Blum's* control tests were all negative.

### OUR OWN TESTS

Our first tests confirmed *Annersten's* observation that the active principle in homozoic extracts can be transferred from alcohol to benzene and ether. As it was essential, from the point of view of obtaining material, to use heterozoic material, we injected extracts of calf bone marrow into rabbit's muscles. These heterozoic injections proved as effective as the homozoic. We therefore preferred to work with heterozoic material (calf-rabbit). Since it seemed that it was possible to transfer the active factor between a number of soluble agents, we made an investigation to discover whether the activity could be collected quantitatively in a particular fraction.

### EXPERIMENTAL METHODS AND ASSESSMENT OF THE RESULTS

We used the original method, injecting the extracts into the rectus femoris muscle of rabbits. The connective tissue membrane, which surrounds the rectus femoris like a capsule, is probably of importance in retaining the injected fluid and in preventing its too rapid diffusion into the neighbouring tissues.

The extract was injected on 4 successive days according to the following schedule:

1st day: 1 ml. extract mixed with 1 ml. physiological saline  
2nd day: 1 ml. extract mixed with 1 ml. physiological saline  
3rd day:  $\frac{1}{2}$  ml. extract mixed with  $\frac{1}{2}$  ml. physiological saline  
4th day:  $\frac{1}{2}$  ml. extract mixed with  $\frac{1}{2}$  ml. physiological saline

If the extract for injection was dissolved in oil or water we began with an alcohol injection:

1st day: 2 ml. of 40 % alcohol  
2nd day: 1 ml. extract  
3rd day: 1 ml. „  
4th day: 1 ml. „

The extracts were prepared so that 1 ml. was equivalent to 0.5 gm. of bone marrow.

Usually, each extract was tested on 10 rabbits and was injected into both thighs of each animal. Thus, each series of 10 rabbits contained a maximum of 20 specimens. After the last injection we usually waited between 2 and 3 weeks before taking the specimen. The animal was then killed; the rectus femoris muscle was removed and fixed immediately in formalin, and the usual histological preparations were made, the sections being cut longitudinally. Under "number of specimens" are counted only those which showed the possibility of bone formation i.e. an ossifiable environment in the form of a definite granulation tissue with its abundant vessel and mesenchymal formation. A "positive" specimen is one showing definite cartilage or bone formation. The figures in brackets after the percentage of positive specimens in each series show the number of specimens with definite reactive granulation tissue, and the number with bone or cartilage formation. Since some animals die during the observation period, and others show no mesenchymal reaction in the muscle, the number of specimens in each series may be less than the original 20.

Thus, a result expressed as 50 % (14:7) means that out of the original 20 specimens 14 showed reactive tissue, and of these 7 showed cartilage or bone formation.

## I. EXTRACTION WITH ACIDIFIED ALCOHOL

Test 1. Preparation: Calf bone marrow

95 % alcohol

Acidified alcohol (1,000 ml. 95 % alcohol +  
50 ml. N/10 HCl)

Benzene

Method: 70 gm. marrow was homogenized in a mortar, and then shaken in a bottle with 210 ml. alcohol for 18 hours. After centrifuging a clear supernatant fluid was obtained. This was decanted and concentrated by evaporation in a water bath to 25 ml., when a clear pale yellow liquid with a residue was obtained. These 25 ml. of alcoholic solution were shaken in a separating funnel with 25 ml. of benzene, and two layers were obtained. The upper, benzene, layer was pale yellow and rather clear; the lower, alcoholic, layer was white and milky. The two layers were separated, and the alcoholic layer was shaken up again with 25 ml. of benzene. The benzene layer was now colourless and rather clear, whereas the alcohol layer was still milky. *The alcohol layer:* the benzene was evaporated in a vacuum: the solution became pale yellow, somewhat opalescent and with some residue. It was diluted up to 140 ml. with 95 % alcohol = *extract A* (rather clear and almost colourless). *The benzene layer:* was reduced to complete dryness in a vacuum and was then dissolved in 10 ml. acid alcohol, giving a yellow solution with some residue. This solution was diluted with 130 ml. 95 % alcohol = *extract AB* (clear and almost colourless).

*Result: Extract A.* 73 % (11:8) positive.

*AB.* 38 % (16:6) positive.

As it was found that after two shakings, activity still remained in the alcohol fraction, further tests were made, using the same method but more thorough shaking.

In *Test 2* the solutions were shaken 3 times with benzene, as in *Test 1*. The benzene fraction obtained gave 7 % positives (14:1). After shaking the same alcoholic solution with benzene 7 more times, no activity could be demonstrated in the combined benzene fractions (12:0). But the alcoholic fraction which had thus been shaken 10 times with benzene still had some activity = 42 % positives (12:5).

In *Test 3* the combined benzene fractions showed after 7 shakings with the alcoholic layer 11 % positive (18:2), while the alcohol fraction had 33 % positives (18:6). In *Test 4* the combined benzene fractions were tested after only 3 shakings with the alcohol fraction and gave 26 % positives (19:5).

## II. EXTRACTION WITH ACIDIFIED ALCOHOL + PETROLEUM ETHER

When the marrow was extracted with acidified alcohol only, it tended to form into round masses, and one could not be certain that the extraction was complete. Therefore, a

combined alcohol and petroleum ether extraction was used and the marrow dispersed to give a homogeneous mixture.

**Test 5. Preparation:** Calf bone marrow

95 % alcohol

Acidified alcohol (see test 1)

Petroleum ether

Benzene

Olive oil

**Method:** 70 gm. marrow was homogenised in a mortar, introduced into a bottle together with 210 ml. acid alcohol + 210 ml. petroleum ether, and shaken for 18 hours. It was then centrifuged for about 20 minutes. The alcohol and the petroleum ether separated, and the undissolved substance sedimented out. The two layers were drawn off separately. The *petroleum ether layer* was evaporated in a vacuum until all the petroleum ether had been driven off. This left a mass, which, after cooling, appeared firm and white. It was dissolved in olive oil = *extract P*.

The *alcohol layer* was evaporated on a water bath in a vacuum to a volume of 35 ml. It was then shaken twice with benzene, and the alcohol layer was diluted with 95 % alcohol = *extract A*.

The *benzene layer*: the two benzene layers obtained by shaking with the alcohol layer were combined and evaporated to complete dryness. The residue was dissolved in 10 ml. acidified alcohol, and then diluted to give *extract B*.

**Result:** *Extract P* = 44 % positives (9:4)

*A* = 28 % — (18:5)

*B* = 23 % — (13:3)

In a similar test, *Test 6*, the alcohol fraction was tested after it had been shaken three times with benzene. *Result* = 40 % positives (10:4), while the combined benzene fractions were inactive (16:0). In the following tests (*Tests 7 and 8*) the combined benzene fractions obtained after 3 shakings of the alcohol fraction were tested alone, and gave 0 % (8:0) and 8 % positives (12:1) respectively.

**Test 9. Preparation:** As in Test 5 + pure acetone.

**Method:** After 24 hours' extraction by shaking, the alcohol and petroleum ether layers were decanted separately. The *alcohol layer* was shaken with petroleum ether 3 times, and each petroleum ether layer was shaken with 95 % alcohol.

The *petroleum ether layer* was shaken with 95 % alcohol and the resulting alcohol and petroleum layers were combined.

The *alcohol fraction* was partially evaporated in a vacuum and shaken three times with benzene. The combined benzene layers were treated as in *Test 5 = extract B*. The remaining alcohol fraction was precipitated with acetone. The precipitate obtained after 24 hours was dried in a dessicator and became yellowish and of a waxy consistency. It was dissolved in 95 % alcohol = *extract A*.

The *petroleum ether fraction* was evaporated in a vacuum until all the petroleum ether had disappeared. The residue, a yellow fat, was precipitated with acetone, and gave a white fairly plentiful precipitate, which was dried, ground to powder and dissolved in olive oil = *P ac*. The acetone was evaporated off the filtrate after the precipitation, and one half of the remaining fat was diluted with olive oil = *extract P*.

Result: <i>Extract A</i>	=	0 %	positives	(14:0)
<i>A ac</i>	=	50 %	—	(14:7)
<i>B</i>	=	72 %	—	(18:13)
<i>P ac</i>	=	0 %	—	(16:0)
<i>P</i>	=	0 %	—	(16:0)

*Test 10* was carried out like *Test 9*, except that the acetone precipitate from the alcohol fraction was dissolved in saline solution. In this series nearly all the preparations showed infection, and no bone formation was obtained (20:0). The alcohol fraction, i.e. the filtrate from the acetone precipitate gave 10 % (20:2), the benzene fraction 32 % (19:6), and the acetone filtrate from the petroleum ether fraction 6 % positives (18:1).

*Test 11* was also carried out like *Test 9*, but in addition one benzene fraction was washed with distilled water. The combined water fractions gave 10 % positives (20:2). The benzene fraction shaken with water was dried with sodium sulphate and then dissolved in 95 % alcohol; it gave no positives (20:0). The part of the benzene fraction which had not been washed with water showed 35 % positives (20:7). The alcohol fraction, i.e. the filtrate left after the acetone precipitation was inactive (20:0), as was also the acetone precipitate from the same fraction, dissolved in saline solution (20:0). The acetone precipitate from the petroleum ether fraction dissolved in alcohol showed weak activity = 6 % positives (18:1).

*Test 12* was made in the same way as *Test 10*. The filtrate obtained after acetone precipitation of the alcohol fraction showed 31 % positives (16:5), while the precipitate dissolved in saline gave 40 % positives (20:8). The acetone precipitate from the petroleum ether fraction was inactive (20:0).

In *Test 13*, carried out in the same way as *Test 11*, the following

fractions were tested: the combined benzene fractions obtained by shaking the alcohol fraction; the alcohol fraction shaken with the benzene; one alcohol fraction which had been washed with distilled water; and the combined water fractions obtained from the benzene washing. All series were negative (20:0).

### CHROMATOGRAPHIC TESTS

In *Test 14*, chromatography was used. The petroleum ether fraction from *Test 6* was used. This extract is a firm, white fat at room temperature; it was melted for each test.

Apparatus and preparation: Chromatogram tube, 20 mm. diameter.  
Aluminium oxide, according to Brockman.  
Petroleum ether.

Method: The extract was dissolved in 25 ml. petroleum ether. The chromatogram, which had no coloured zones, was divided into 3 equal columns, each extracted separately in petroleum ether + some methanol.

Columns 1 and 2 from 2 tests were tested. The petroleum ether was evaporated in a water bath. The remaining fat was dissolved in olive oil. *Result*: Both series were inactive (17:0 and 20:0).

In *Test 15* the dried benzene fraction from *Test 11* was used as a raw extract; it unfortunately proved to be inactive. The same technique was used. 3 chromatograms were tried. *Result*: Both series were inactive (10:0 and 10:0).

### III. TESTS WITH VARIOUS METHODS OF EXTRACTION

#### 1. Acid alcohol + ethyl ether:

In *Test 16* the alcohol-ether layer obtained after the extraction could not be separated. It was evaporated in a vacuum to 35 ml., and shaken twice with benzene. The resulting benzene solutions were combined and evaporated to complete dryness, and the residue was dissolved in alcohol. *Result*: 30 % positives (20:6).

*Test 17* was performed in the same way as *Test 16*, except that the evaporated alcohol-ether layer was shaken with benzene 7 times instead of only twice. The combined benzene layers were evaporated to complete dryness. The residue was a firm, white fat after cooling; one part of it was dissolved in oil, and one part in alcohol. *Result*: the oil solution gave 0 positives (20:0), and the alcohol solution 25 % positives (20:5).



## 2. Benzene. (Soxhlet):

*Test 18.* The marrow was dried with  $\text{Na}_2\text{SO}_4$ . After the Soxhlet extraction the benzene solution was evaporated to complete dryness. Part of the residue was dissolved in oil. *Result:* 25 % positives (12:3).

## 3. 95 % alcohol + petroleum ether:

*Test 19.* After the extraction, the two layers were separated. Only the alcohol fraction was used. It was partly evaporated, and shaken 3 times with benzene. The combined benzene layers were evaporated to dryness. The residue was dissolved in alcohol. *Result:* 59 % positives (17:10). The alcohol layer was diluted with 95 % alcohol. *Result:* 47 % positives (15:7).

## 4. Petroleum ether:

*Test 20.* When the marrow from Test 4 had been shaken with acid alcohol, and the alcohol layer had been filtered off, the rest of the marrow was this time not discarded, but was shaken with petroleum ether. The petroleum ether layer was then evaporated to dryness, and the residue was dissolved in olive oil. *Result:* 0 positives (19:0).

## CHEMICAL INVESTIGATIONS OF THE BONE MARROW EXTRACTS

*Lieberman-Burchard's* sterol reaction was performed on 10 different extracts. It was negative in 4; their total of positives was 54 % (56:30). In the other 6 extracts it was positive; their total of positives was 26 % (108:28).

*Tests for phosphatase* were made on the extracts of tests 6, 17 and 19, and were all negative.

The *Biuret reaction* was negative in extracts 1 A and 5 A.

The solubility of the acetone precipitates was as follows:

insoluble in olive oil at room temperature

partly soluble in alcohol at 37° C.

completely soluble in distilled water at room temperature.

The water fractions after washing the benzene in Test 13 gave a positive reaction for unsaturated fatty acids (decoloration of  $\text{KMnO}_4$ ).

## SUMMARY

*Levander* and others showed that alcoholic extracts of bone and bone marrow contain a factor with a definite osteogenetic

activity, e.g. injection of the extracts into the quadratus femoris of rabbits resulted in the formation of bone or cartilage in the muscle. In the present investigation we have tried to collect the osteogenetic activity quantitatively in one or other of the dissolving agents by shaking an alcoholic extract of bone marrow with benzene. In this we were unsuccessful; in fact it was found that the activity stubbornly remained in the alcohol fraction. After shaking the alcohol extract with two separate solutions of benzene the alcohol fraction gave 73 % positives (Test 1), and the benzene fraction only 38 %. After shaking the alcohol extract with 10 separate benzene solutions, the alcohol fraction was still active (42 % positives), while the last benzene fraction was completely inactive. In the tests with extracts in acid alcohol the alcohol fraction gave 46 % positive results (41:19) and the benzene fraction 17 % (79:14). In tests with extracts in acid alcohol + petroleum ether, the alcohol fraction gave 30 % (98:29), and the benzene fraction 27 % positives (124:33).

In two tests it was possible to collect a considerable activity in the acetone precipitate obtained from an alcohol fraction (40 % and 50 % positives respectively), the filtrate after the precipitation being considerably less active. The combined precipitates gave 28 % (54:15) and the combined filtrates 10 % (70:7) positives.

The activity of the extracts from the petroleum ether fraction was remarkably low; good result (44 %) was obtained in only one test. All the petroleum ether extracts gave an average of only 4 % positives (154:6). After chromatography the extracts were completely inactive; in one test this was probably due to inactivity of the original benzene extract, in the other, a petroleum ether extract, which usually has a very low activity, was used. Therefore, in both cases the original extract was probably inactive.

Of the two water extracts, one gave a weak positive result (10 %) and one was inactive; the former came from a positive (35 %) and the latter from a negative benzene extract.

The rather large number of series with completely negative results, the extracts being altogether inactive, might be regarded as control tests. If all the positive and all the negative series are collected into 2 groups, one obtains the figures 456:137 (30 %), and 437:0. Statistically, this proves that the positives cannot be due to pure chance.

The experiments have shown that the results obtained with heterozoic material are comparable with those obtained with homozoic.

It would be premature to attempt to base any chemical classification of the osteogenic factor on the results obtained here. Some conclusions may, however, be drawn. It is interesting that it is not possible to extract all the active factor out of an alcohol fraction by means of benzene, and that the particular solvent for sterols and lipoids, petroleum ether, fails to extract the active factor from the alcohol. This supports the opinion that the active factor is not a pure sterol or lipid, which is also confirmed by the low activity of the pure petroleum ether extracts. Further, most extracts gave negative reactions when tested for sterols. The activity of the acetone precipitates from the alcohol extracts suggests a phosphatide, but this is contradicted by their solubility in distilled water, and their relative insolubility in oil:

## RESUME

*Levander* et d'autres ont montré que les extraits d'alcool d'os et de moelle osseuse contiennent un facteur possédant une activité ostéogénétique définie. Ainsi, il résulte de l'injection de ces extraits dans le quadratus femoris des lapins une formation osseuse ou cartilagineuse dans le muscle. Dans les présentes recherches, nous avons essayé de recueillir la donnée quantitative de l'activité ostéogénétique en mélangeant l'extrait d'alcool de moelle osseuse dans divers dissolvants à du benzène. Nous n'avons eu aucun succès ; en réalité il a été constaté que l'activité reste opiniâtement dans la fraction

d'alcool. Après avoir mélangé l'extrait d'alcool avec des solutions séparées de benzène, la fraction d'alcool donna 73 % de réactions positives ( Test 1 ) et la fraction de benzène 38 % seulement. Après avoir mélangé l'extrait d'alcool avec 10 solutions séparées de benzène, la fraction d'alcool était encore active ( 42 % réactions positives ), tandis que la dernière fraction de benzène était complètement inactive. Dans les tests avec extraits dans des acides d'alcool, la fraction d'alcool donna 46 % de résultats positifs et la fraction de benzène 17 %. Dans les tests avec des extraits bruts dans des acides d'alcool + éther de pétrole, la fraction d'alcool donna 30 % ( 41 : 19 ), et la fraction de benzène 27 % réactions positives ( 124 : 33 ).

Dans deux tests, il a été possible de recueillir une activité considérable de la précipitation d'acétone obtenue d'une fraction d'alcool ( 40 % et 50 % réactions positives respectivement ), la substance filtrée après la précipitation étant beaucoup moins active. Les précipitations combinées ont donné 28 % ( 54 : 15 ) et les substances filtrées combinées 10 % ( 70 : 7 ) positives.

L'activité des extraits de la fraction de l'éther de pétrole était curieusement basse ; un bon résultat ( 44 % ) a été obtenu dans un seul des tests. Tous les extraits d'éther de pétrole ont donné une moyenne n'atteignant que 4 % de réactions positives ( 154 : 6 ). Après la chromophotographie, les extraits étaient complètement inactifs ; dans un test ceci était probablement dû à l'inactivité de l'extrait primitif de benzène, dans l'autre, on a utilisé un extrait d'éther de pétrole dont l'activité est généralement très basse. C'est probablement pourquoi l'extrait original est resté inactif dans ces deux cas.

Sur deux extraits d'eau, l'un a donné un faible résultat positif ( 10 % ) et l'autre est resté inactif ; le premier provenait d'une réaction positive ( 35 % ), le dernier d'un extrait de benzène négatif.

Le nombre relativement élevé de séries donnant des résultats absolument négatifs, les extraits étant dans l'ensemble

inactifs, doivent être considérées comme des tests de contrôle. Si toutes les séries positives et toutes les séries négatives sont rangée en deux groupes, on obtient les données 456 : 137 ( 30 % ) et 437 : 0. D'un point de vue statistique, ceci prouve que les données positives n'ont pas été obtenues par le effet du hasard.

Les expériences ont montré que les résultats obtenus avec un matériel hétérozoïque sont comparables à ceux d'un matériel homozoïque.

Il serait prématuré de vouloir établir une classification chimique du facteur ostéogénique sur les résultats obtenus ici. On peut toutefois en tirer certaines conclusions. Il est intéressant de constater qu'il n'est pas possible d'extraire tout le facteur actif d'une fraction d'alcool au moyen du benzène, et notamment que le solvant particulier des stérols et des lipoides, l'éther de pétrole, n'arrive pas non plus à extraire le facteur actif de l'alcool. Ceci appuie l'hypothèse que le facteur actif n'est pas un pur stérol ou lipoïde, ce qui est confirmé également par la faible activité des extraits de pur éther de pétrole. Par ailleurs, les extraits les plus actifs ont donné des réactions négatives lorsqu'ils ont été essayés comme stérols. L'activité des précipitations d'acétone des extraits d'alcool semble indiquer qu'il y a phosphatisation, mais ceci est contredit par la solubilité des précipitations dans l'eau distillée et leur insolubilité relative dans l'huile.

#### ZUSAMMENFASSUNG

Levander und andere Autoren zeigten, dass alkoholische Extrakte von Knochen und Knochenmarken einen Faktor mit definitiven osteogentischen Eigenschaften enthalten. Injektion der Extrakte in den quadratus femoris von Kaninen resultierte in der Bildung von Knorpel oder Knochen im Muskel. In den vorliegenden Untersuchungen haben wir versucht die osteogenetische Aktivität quantitativ in dem einen oder dem anderen der lösenden Agentia zu sammeln, indem wir einen alko-

holischen Extrakt von Knochenmark mit Benzen ausschüttelten. Wir waren damit nicht erfolgreich. Wir fanden in der Tat dass die Aktivität ständig in der Alkoholfraktion zurückblieb. Nach Ausschüttelung des Alkoholextraktes mit zwei gesondeten Benzenlösungen, gab die Alkoholfraktion 73 % positive Resultater (Versuch 1), und die Benzenfraktion nur 38 %. Nach Ausschüttelung des Alkoholextraktes mit 10 gesondeten Benzenlösungen, war die Alkoholfraktion noch immer aktiv (42 % positive), während die letzte Benzenfraktion vollständig inaktiv war. Die Versuche mit Extrakten mit Säure-Alkohol gaben in der Alkoholfraktion 46 % positive Resultater (41:19) und der Benzenfraktion 17 % (79:14). In Versuchen mit Extrakten mit Säure-Alkohol und Petroleumäther gab die Alkoholfraktion 30 % (98:29) und die Benzenfraktion 27 % positive Resultater (124:33).

In zwei Versuchen was es möglich eine bedeutende Aktivität in dem Azeton Präzipitat, das von der Alkoholfraktion erhalten wurde, zu sammeln (40 % respektive 50 % positive Resultater). Das Filtrat nach der Prebipitation war bedeutend weniger aktiv. Die Präzipitate zusammen gaben 28 % (54:15) und die Filtrate zusammen gaben 10 % (70:7) positive Resultater.

Die Aktivität der Extrakte der Petroleumätherfraktion war auffallend niedrig. Nur in einem Versuch (44 %) wurde ein gutes Resultat erzielt. Die Petroleumätherextrakte zusammen gaben einen Durchschnitt von nur 4 % positiven Resultaten (156:6). Nach Chromatographie waren die Extrakte vollständig inaktiv. In einem Versuch war die Ursache wahrscheinlich Inaktivität des ursprünglichen Benzenextraktes, in den anderen wurde ein Petroleumätherextrakt, der gewöhnlich eine sehr geringe aktivitet hat, verwendet. Deshalb war in beiden Fällen der ursprüngliche Extrakt wahrscheinlich inaktiv.

Von den zwei wässrigen Extrakten gab einer schwach positive Resultater (10 %) und der andere war inaktiv. Der erstere kam von einem positiven Benzenextrakten (35 %) und der letztere von einem negativen Benzenextrakt.

Die ziemlich grosse Anzahl von Reihenfolgen mit vollständig negativen Resultat, bei inaktiven Extrakten, kann als Kontrolproben angesehen werden. Wenn man alle positiven und alle negativen Serien in zwei Gruppen sammelt, erhält man die Zahlen 456:137 (30 %) und 437:0. Das beweist Statistisch, dass die positiven Resultate nicht auf reinem Zufall beruhen können.

Die Versuche haben gezeigt, dass die Resultate, die man mit heterozoischem Material erhält, verglichen werden können mit denen, welche man mit homozoischem erhält.

Es würde verfrüht sein, zu versuchen eine chemische Klassifikation des osteogenetischen Faktors auf den hier erhaltenen Versuchen zu begründen. Gewisse Schlussfolgerungen kann man jedoch ziehen. Es ist interessant, dass man nicht den gesamten aktiven Faktor eines Alkoholextraktes mit Hilfe von Benzen extrahieren kann, und dass die spezielle Solvens für Sterol und Lipoid, Petroläther, nicht imstande ist den aktiven Faktor vom Alkohol zu extrahieren. Dies unterstützt die Ansicht dass der aktive Faktor nicht ein reines Sterol oder Lipoid ist, welche Ansicht auch durch die geringe Aktivität der reinen Petrolätherextrakte unterstützt wird. Ausserdem gaben die aktivsten Extrakte negative Reaktionen, wenn untersucht auf Sterole. Die Aktivität der Azetonpräzipitate von Alkoholextrakten deutet auf Phosphatide hin, aber dagegen spricht die Löslichkeit der Präzipitate in destiliertem Wasser und ihre relative Unlöslichkeit in Öl.

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## EXPERIMENTAL INVESTIGATIONS INTO THE HEALING OF FRACTURES

BY

VIGGO ESKELUND & CLAUS MUNK PLUM

I.

### HEALING OF FRACTURES OF THE FEMORAL DIAPHYSIS IN RATS

#### *Introduction.*

The healing of fractures has aroused great interest ever since the days of *Galen* and *Hippocrates* and has been the object of numerous investigations. In 1940, according to *Urist* and *Johnson*, there were more than 4000 publications on this subject and this figure has since been considerably increased.

The questions arousing special interest have been the periosteal and endosteal formation of bone, direct and indirect ossification, the factors which might have an influence on the healing of bone, and, during the last few decades, questions concerned with the transplantation of bone and osteosynthesis. Investigations have been based mainly on experimental fractures, clinical and histological studies, and radiography.

Gradually, agreement about the main features of the healing of fractures has been reached, but different investigations still show considerable differences of detail.

*Urist* and *Johnson's* work of 1943 contains an excellent survey of the various stages of healing of fractures and a copious bibliography, to which reference may be made.



Briefly, the healing of a fracture in man takes place as follows: Immediately after a bone is fractured a haematoma forms at the site of the fracture: it contains large and small fragments of bone, of bone marrow, and of the surrounding muscles, ligaments, fasciae and, possibly, articular cartilage and capsular tissue. Very soon aseptic inflammatory changes and processes of organisation take place within the haematoma. The resulting swelling at the site of the fracture is termed *procallus*.

The haematoma is invaded by a highly vascularized granulation tissue from the surrounding tissues and at the same time the periosteum, and to some extent the endosteum, proliferates in the circumference of the fracture, forming, in the case of the periosteum, an annular cancellous thickening of the fracture ends, which become club-shaped. These periosteal formations gradually grow beyond the fractured surfaces, across the more or less organised haematoma, and are seen in sections to form a bridge-like osseous connection between the fragments. The granulation tissue which has replaced the haematoma contains hyaline cartilage, fibrocartilage and fibrous cicatricial connective tissue. Thus, the thickening at the site of the fracture, the true callus, consists at this stage of a disc of connective and cartilaginous tissue lying between the fragments and between the bone formed externally by periosteal and centrally by endosteal bone formation.

The actual consolidation of the fracture by ossification begins early but is completed very late. Like "primary healing" its course is mainly centripetal, the fibrocartilaginous callus disc being gradually replaced by osseous tissue growing in from the external callus. There seems to be no sharp delimitation between osteoid and osseous tissues.

As new bone is formed, loose tissue fragments and the fractured ends are resorbed and demineralized, and for a long time after osseous union is established reorganisation continues, superfluous tissue being removed and the new structure as far as possible adapted to the static and mechanical conditions.

The time required for the healing of a fracture varies widely: it depends on many different factors, such as the type and site of the fracture, the amount of displacement, the mobility and the patient's age. Occasionally a fracture does not unite, and a pseudarthrosis is formed.

In animals the healing of fractures is the same as in man, with the formation of *procallus*, fibrocartilaginous callus and osseous callus.

The animals most frequently used for experimental studies of the healing of fractures have been rats, rabbits and guinea-pigs. *Hertz* (1936) used 4-week-old rats; he fractured the

fibula by means of a special forceps, constructed by himself, and killed the animals from 4 to 50 days later. From a study of 27 animals treated in this way, he found that the haematoma was completely organised in 4 days and the callus increased in size up to the tenth to fourteenth day and then decreased. After 35 days it could not be demonstrated macroscopically. The mobility at the site of the fracture steadily decreased, and after 22 days only a very slight "springiness" remained. In 27 guinea-pigs treated by the same method he found that the fracture was firm after 26 days, and that the callus was removed in about 50 days.

*Urist* and *McLean* used over 400 7-week-old rats; they fractured the tibia and examined the callus histologically, in particular the relation of calcification to osteogenesis. The fracture was observed for 24 days; it was not immobilised. No details of the time of union or of the mobility at the fracture site at the different dates are given.

### *Methods and Assessment.*

The present work was designed to show the course of normal healing of fractures in rats, using a particular fracture. Special attention was paid to the time and degree of healing.

We first tried Hertz's method of fracturing the fibula but we abandoned it, partly because of the difficulty of producing the fracture and partly because exact radiographic control was not possible. Instead manual fracture of the femur proved to be fairly easy and to be better suited to radiographic study. White laboratory rats, aged 4-5 months were used; they were kept in single cages on a standard vitamin-containing diet and thrived normally. The femur was fractured manually under ether anaesthesia. Immobilization of the fractures proved impossible, so there was usually considerable deformity. Otherwise, the fracture seemed to cause comparatively slight inconvenience to the animals. After 5 or 6 days they stood on their hind legs and jumped about as they had done before the fracture. In order to make the material more homogeneous.

only fractures of the middle third of the bone were included. Fractures of the lower third appeared to heal far more rapidly. The degree of healing was assessed on the basis of *the mobility, radiographic and histological appearances.*

### *Material.*

The material comprises 271 rats with fracture of the middle third of the left femur. As the object of the examination was to determine the course of the normal healing of fractures under the given conditions, the animals were usually killed at intervals of about a week. A small number of animals was also killed at shorter intervals during the first four weeks with a view to following the processes of healing histologically, while 13 animals were not killed until 8 months after the fracture. In order to obtain both a qualitative and a quantitative expression of the healing, the numbers of animals killed after 14, 21, 28 and 56 days respectively were relatively large. The distribution was as follows:

Days after fracture	Number of animals
2	1
4	2
7	8
9	4
11	5
14	44
16	2
21	38
24	2
28	57
35	12
42	5
49	5
56	51
63	5
64	2
70	5
84	5
94	5
243	13

The larger groups were collected at different seasons and from different litters in order to reduce errors as far as possible.

*Healing of the Fractures Assessed According to Degree of Firmness.*

The firmness of a fracture is the best criterion of its healing, except in impacted fractures, which are very rare in fractures of the diaphysis. The mobility at the fracture site was tested immediately after the animals had been killed and the soft parts had been removed. One fragment was fixed, and then the range of movement of the other fragment was measured in degrees with a protractor. If the range was greater in one plane than in the other, the greater range was recorded. Ranges of more than  $90^\circ$  are recorded as  $120^\circ$ ; if between  $5$  and  $10^\circ$ , for example, as  $10^\circ$ . Arranged according to the time after fracture the following ranges of movement were found:

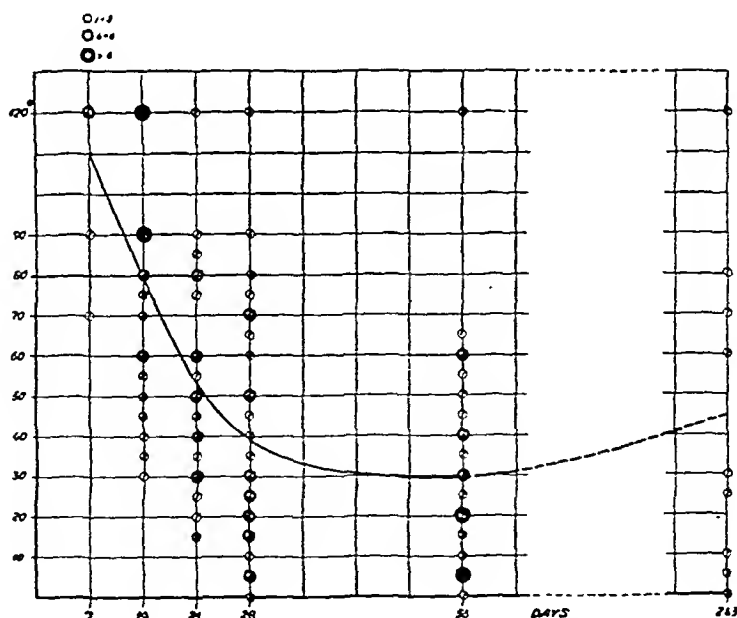


Fig. 1.

Curve showing the degree of firmness in relation to time of healing.

Days after fracture	Number of animals	min.	Mobility max.	mean (120°)
2	2	120°	120°	(120°)
4	2	120	120	
7	8	70	120	110
9	4	120	120	
11	5	90	120	
14	44	30	120	78
16	2	90	90	
21	38	15	120	53
24	2	45	90	
28	57	0	120	37
35	12	5	120	
42	5	0	75	
49	5	0	120	
56	51	0	120	28
63	5	30	120	
64	2	15	60	
70	5	10	35	
84	5	10	120	
94	5	15	120	
243	13	0	120	(45)

These figures, and figure 1 show that the mobility was complete or very large during the first fortnight, and firm union did not occur before 4 weeks. The mean values of mobility were computed only for the larger groups; they show a fall during the first 8 weeks. After 8 months they were somewhat higher and quite a considerable number of fractures did not become firm during the observation period, presumably due to the formation of a pseudarthrosis. Further, a group of 13 subjects is not large enough for any definite conclusions. For all groups there was a very considerable standard deviation.

Cumulative curves of the larger groups show an initial marked and later a decreasing displacement to the left. The displacement decreases with the age of the fracture (see Fig. 2).

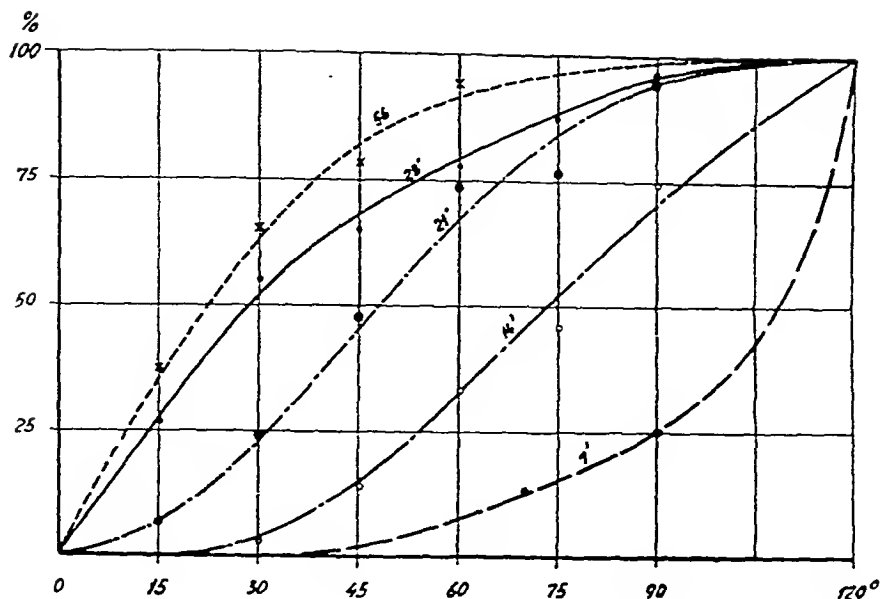


Fig. 2.

Cumulative curves showing degree of firmness after 7, 14, 21, 28 and 56 days.

### *Healing of Fractures Assessed by Means of X-rays.*

Nearly all fractures were radiographed in two planes after removal of the soft parts. In addition, in most cases the range of movement, the shortening and the diastasis were measured, and the nature and position of the fracture were determined. The actual basis of the assessment was, however, the periosteal formation of new bone and the resorption of the fractured ends, assessed at values from 0 to 3. The faintest periosteal reaction, a very narrow, not very dense shadow, was assessed as  $\frac{1}{2}$ ; a narrow, but rather dense shadow as 1; a fairly marked periosteal thickening with perhaps adaption of the fractured ends at these thickenings, as 2; while the maximum value 3 was reserved for the rather few cases in which complete osseous healing occurred.

The assessment of the periosteal reaction gave the following results:

Days	No. of animals	min.	Periosteal reaction max.	mean
2	1	0.0	0.0	
4	2	0.0	0.0	
7	8	0.0	0.5	0.25
9	4	0.0	0.5	
11	5	0.0	0.5	
14	44	0.0	0.5	0.53
16	2	0.5	1.0	
21	38	0.5	1.5	0.84
24	2	1.0	1.0	
28	57	0.5	2.0	1.14
35	12	0.5	2.5	
42	5	1.0	2.0	
49	5	0.5	1.5	
56	51	0.5	3.0	1.63
63	5	0.5	2.0	
64	2	1.0	2.5	
70	5	1.0	1.5	
84	5	0.5	1.0	
94	5	0.5	1.0	
243	13	0.5	2.0	1.20

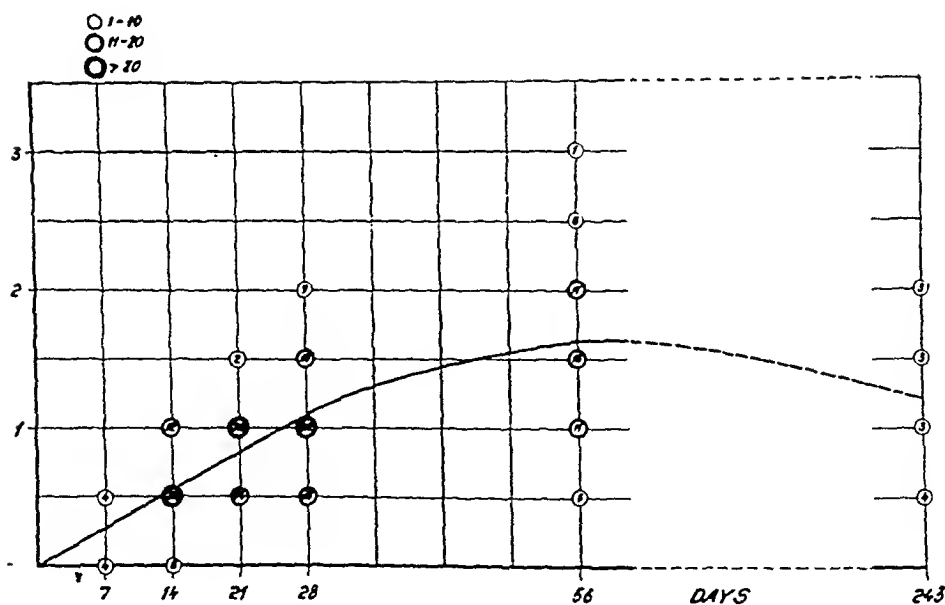


Fig. 3.

Curve showing healing, as judged by the periosteal reaction.

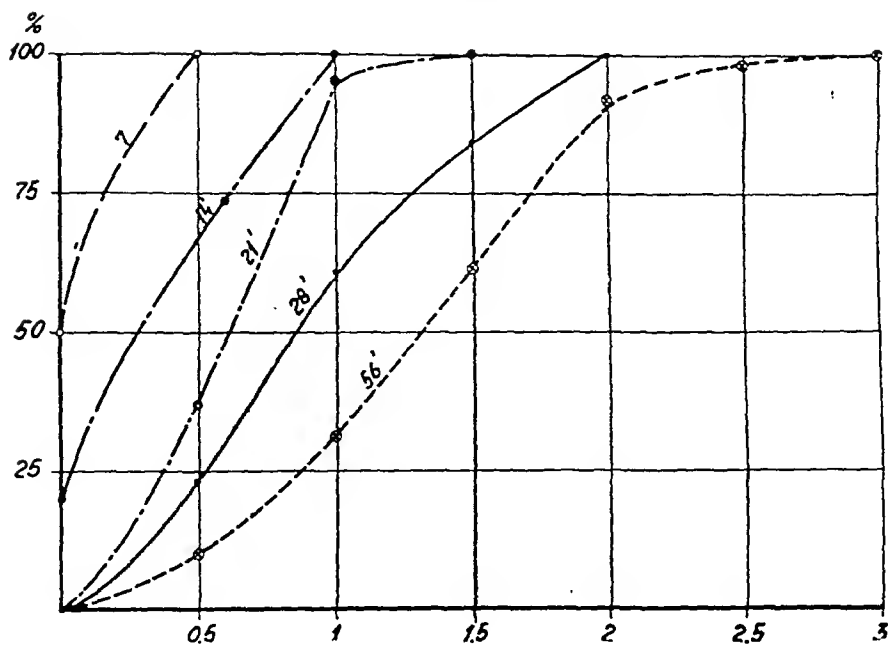


Fig. 4.

Cumulative curves showing the periosteal reaction after 7, 14, 21, 28 and 56 days.

In the larger groups the mean figures show that by the end of a week the reaction is faint and that it then steadily increases. It reaches its maximum of 1.63 after about 8 weeks (see Fig. 2, page 439). After 243 days the figure is lower, presumably because the callus is being remodelled, and, when a pseudarthrosis develops, partly resorbed. The minimum figures show that there was a visible periosteal reaction after 2 weeks in all cases, but that some, irrespective of their duration, had only a very slight tendency to healing.

The cumulative curves show a quite even displacement to the right in the groups examined between the 7th and 56th days. The distance between the curves for 28 and 56 days, as compared with that between the cumulative curves of the other assessments, is relatively large (see Fig. 4).

The resorption was assessed in the following way: slight abrasion and some rarefaction of the fractured ends, 1; a fairly pronounced rarefaction with some blurring of the cortex and rounding of the fractured ends, 2; marked atrophy



of the fractured ends and possible formation of a new articular cavity with pseudarthrosis, 3. The following results were obtained:

Days	No. of animals	min.	Resorption max.	mean
2	1	0.0	0.0	
4	2	0.0	0.0	
7	8	0.0	0.0	0.0
9	4	0.0	0.0	
11	5	0.0	0.5	
14	44	0.0	1.0	0.36
16	2	0.5	0.5	
21	38	0.5	1.0	0.76
24	2	0.5	1.0	
28	57	0.5	2.0	1.14
35	12	0.5	2.0	
42	5	1.5	2.0	
49	5	0.5	2.0	
56	51	0.5	2.5	1.53
63	5	0.5	2.0	
64	2	1.5	2.0	
70	5	1.5	3.0	
84	5	1.0	2.0	
94	5	2.5	3.0	
243	13	1.0	3.0	1.50

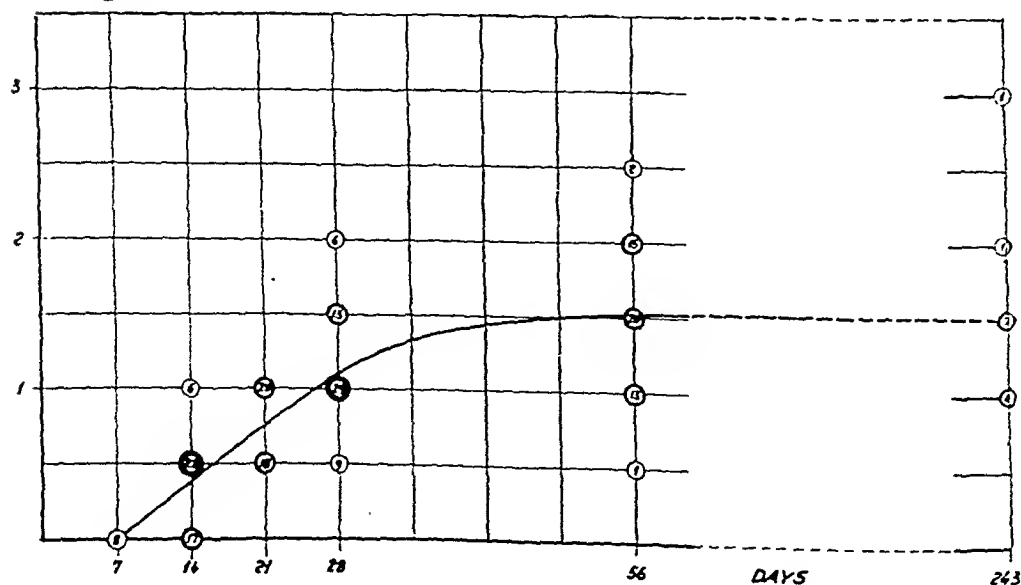
○ 1-10

○ 11-20

● &gt; 20

Fig. 5.

Curve showing the resorption, as judged from radiographs.



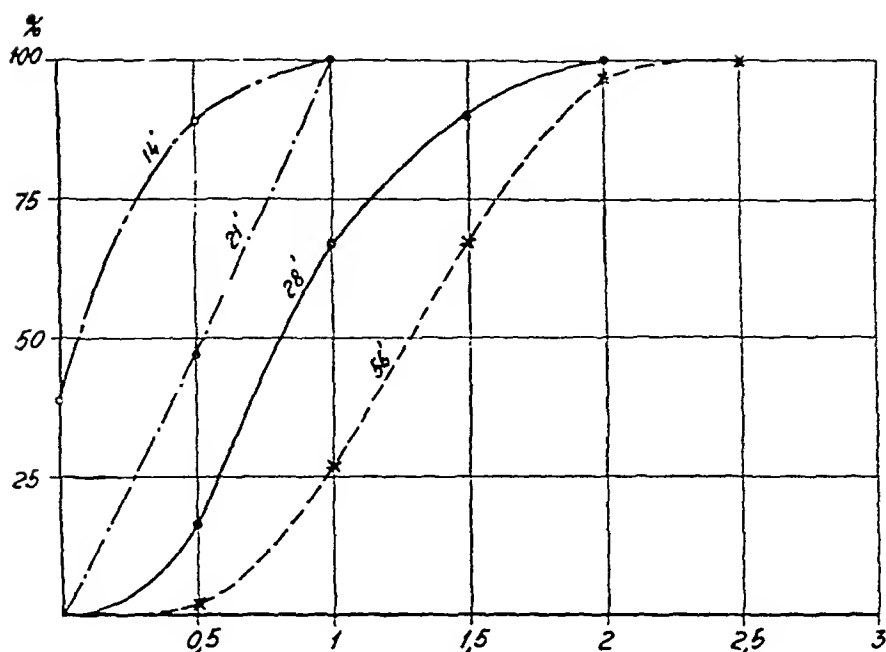


Fig. 6.

Cumulative curves showing the resorption (as judged from radiographs) after 14, 21, 28 and 56 days.

†

Thus it appears that the resorption begins in the second week, increases steadily until about the seventh week, then remains fairly constant. Roughly speaking, the curve (Fig. 5, page 442) follows that showing the periosteal reaction, but it begins a little later and does not fall towards the end of the period of observation, when the bone becomes more compact. At first, the cumulative curves show some displacement to the left as compared with the curve for the periosteal reaction, but, later, they fall together with it. (Fig. 6).

(Dr. V. *Thayssen* kindly interpreted some of the radiographs).

*Histological Examination and Assessment of the  
Healing of Fractures.*

The sections for microscopy were prepared after decalcification (nitric acid, 5 per cent; ammonium ferric sulphate solution, 3 per cent; in the ratio 25:1 c. c.) of the isolated, formalin-fixed bones. These were embedded in paraffin and longitudinal sections were made through the callus. The sections were stained with haematoxylin-eosin and with van Gieson-Hansen's stain. Cutting the sections proved to be technically rather difficult and in some cases numerous sections had to be cut before the correct plane was reached.

These sections do not of course give a complete picture of the processes of healing, as only a small part of the fracture could be observed. We considered the possibility of cutting serial sections but abandoned the idea because of the large number of bones being studied.

A number of details which seemed to have importance for the various stages of the process of healing were selected from the motley histological picture of the fractures; they were assessed, like the radiographs, at values from 0 to 3. Our aim was to obtain a numerical expression of the healing by computing the mean figure of the various assessments. In this way we assessed the following details of the histological picture: haemorrhage, inflammatory infiltration, cavity in the callus, closure of the medullary cavities, periosteal formation of bone and cartilage, other formation of bone and cartilage, the size of the medullary cavity in the newly-formed periosteal tissue and the resorption of bone.

At the time of fracture there is a fairly large *haemorrhage* from the torn vessels; it is, however, quite soon organised and resorbed. Thus, groups of 7 or more subjects showed the following results:

Days	No. of animals	min.	Haemorrhage	
			max.	mean
7	7	1	2.5	1.64
14	15	0	2.0	0.30
21	15	0	1.0	0.27
28	57	0	2.0	0.13
56	14	0	1.0	0.07
243	13	0	0.0	0.00

Thus these figures and also those from the intervening smaller groups show, as might be expected, that the haemorrhage has its maximum immediately after the fracture. It rapidly diminishes, and after 14 days extravasation was seen in only 4 out of 15 cases, and later only few and scattered haemorrhages were observed, usually only in fractures which were fairly mobile. These presumably secondary haemorrhages were probably due to trauma when the animals were removed from the cages. These figures and Fig. 7, page 446, show that the actual fracture haematoma is largely resorbed in the course of 14 days.

Very soon after fracture an aseptic *inflammatory reaction* develops at the site of the fracture, in response to the tissue destruction and haemorrhage. The haematoma is gradually replaced by a granulation tissue rich in cells and vessels and infiltrated with polymorphonuclear leucocytes, lymphocytes, plasma cells and phagocytic cells. Gradually this inflammatory reaction passes into a chronic stage. The fibroblasts in the granulation tissue become more plentiful and finally fibrous scar tissue is formed. The cellular infiltration persists longest in the outer layers of the callus where necrotic muscle fibrils, injured by the fracture, are degenerating.

The quantitative assessment gave the following results for the larger groups:

Days	No. of animals	min.	Inflammation	
			max.	mean
7	7	1	2.0	1.57
14	16	0	2.0	1.13
21	15	0	1.5	0.47
28	57	0	1.0	0.13
56	14	0	2.0	0.21
243	13	0	1.0	0.08

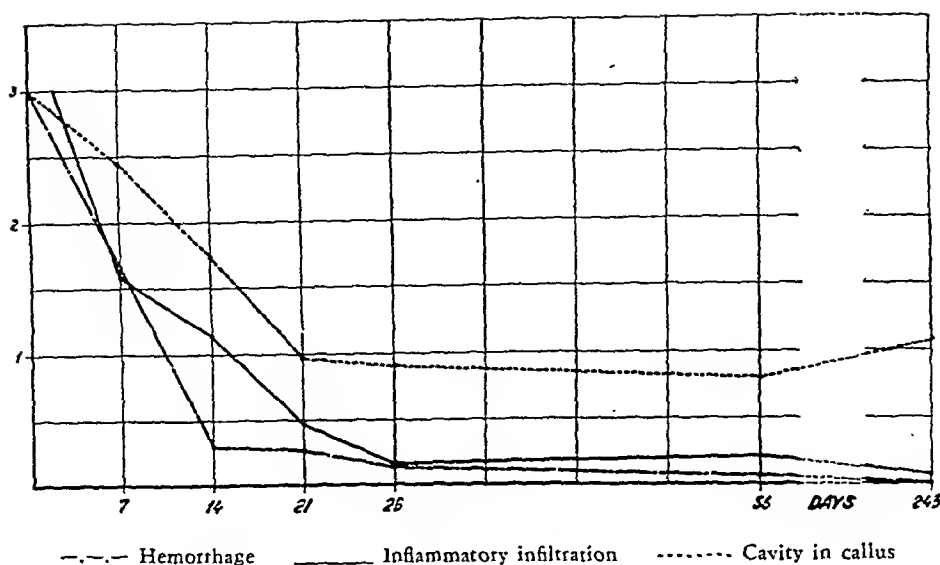


Fig. 7.

Curves showing haemorrhage, inflammatory reaction and cavity in callus.

Thus this material and Fig. 7 show that the inflammatory reaction reaches its maximum on the second to third day after the fracture. It then decreases rapidly during the first week and rather more slowly during the next two weeks, by the end of which time it has largely subsided, though a diffuse, scanty infiltration may still be found many weeks later. Marked inflammatory changes were found in a few fractures after 2 or 3 months; they were presumably due to secondary infection.

The central part of the callus usually contains a cavity which gradually becomes smaller as healing proceeds. At first this cavity is enclosed by the fractured ends of the bones and by loose granulation tissue, often containing deposits of fibrin. Later, it is enclosed by denser fibrous tissue. In the cases where a pseudarthrosis develops the articular cavity is enclosed by cartilage-covered osseous surfaces and connective tissue. In some cases, and particularly in fractures with much

displacement, two smaller cavities are found, one round each bone end. If the fracture is firm, or nearly firm, the cavities are, usually small or completely obliterated. A quantitative assessment of the large groups of the material gave the following results:

Days	No. of animals	min.	Cavity in callus	
			max	mean.
7	7	1	3.0	2.43
14	15	0	3.0	1.73
21	15	0	3.0	0.97
28	55	0	2.0	0.90
56	14	0	2.0	0.79
243	13	0	2.0	1.08

This table and Fig. 7, page 446, show that the cavity becomes fairly steadily smaller during the first 3 weeks; it then remains rather constant at a mean value of about 1 for the rest of the period of observation. By the end of 8 months there even seems to be a slight rise in the curve, presumably with the formation of a pseudarthrosis with larger cavities. Only 2 out of the 13 fractures in this group showed no cavity.

Immediately after the fracture the medullary cavities are open, and usually there is necrosis of the medullary tissue adjoining the fractured surface. *Closure of the medullary cavity*, which is a feature of constant occurrence in the processes of healing, takes place in the following manner. First, the necrotic medullary tissue is resorbed and replaced by a disc of loose connective tissue. This soon becomes more dense, and strands of hyaline fibrils develop and form the basis for the osseous tissue which closes the medullary cavity. This disc of bone varies in thickness; sometimes it forms the starting point of an additional central formation of new bone. In the assessment given below, closure of the connective tissue is assessed as 1, immature osseous tissue as 2, and mature osseous tissue as 3.

Days	No. of animals	Closure of medullary cavity		
		min.	max.	mean
7-9	9	1.0	2.5	2.00
14	9	2.0	3.0	2.89
21	11	2.0	3.0	2.91
28	41	2.5	3.0	2.98
56	11	3.0	3.0	3.00
243	12	3.0	3.0	3.00

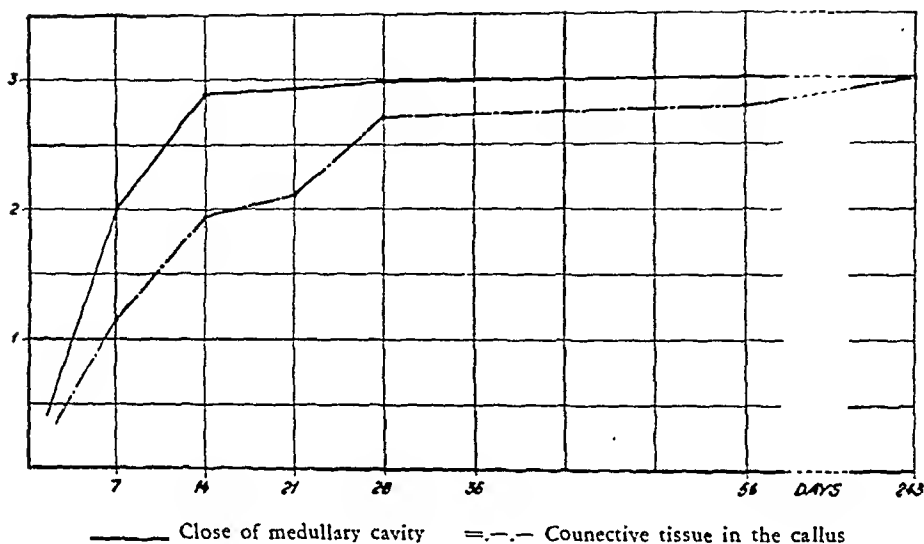


Fig. 8.

Curves showing *closing* of medullary cavity, and maturation of connective tissue in the callus.

This table and Fig. 8 show that the osseous closure of the medullary cavity has begun by the end of one week and is almost complete by the end of two weeks. It seems to be quite independent of the actual course of healing of the fracture. In some cases it is seen to be penetrated by new vessels from the medullary cavity at rather a late stage in the course of healing of the fracture. When union is complete, the disc is presumably resorbed, but this was not observed.

*The periosteal reaction*, with new bone formation, begins very early. First there is a rapid proliferation of the cells in

the deepest layers of the periosteum. This is followed by the formation of collagenous fibrils between the cells, which are gradually transformed into typical osteoblasts; these are found on the surface of broader strands of collagenous fibrils. The tissue becomes osteoid and is then transformed by calcification into true bone. Usually, the new bone formation extends well beyond the actual callus mass. The thickness of the periosteal new bone varies considerably, not only from fracture to fracture, but also on the two fractured ends and on different aspects of one bone. It is often most vigorous on the side of the lesser angle. between the fractured ends. On section the thickening is found to begin at, or, if there is necrosis of the fractured end, a short distance from the fracture line. Its thickness sharply increases, then steadily decreases with the distance from the seat of the fracture. The assessment of the degree of the reaction is according to the same scale as for assessment on the radiographs.

Days	No. of animals	Periosteal formation of new bone		
		min.	max.	mean
7	7	0.5	1.5	1.07
14	14	0.5	2.0	1.29
21	15	0.5	2.0	1.50
28	57	0.5	3.0	1.96
56	14	0.5	3.0	1.79
243	13	1.0	3.0	1.85

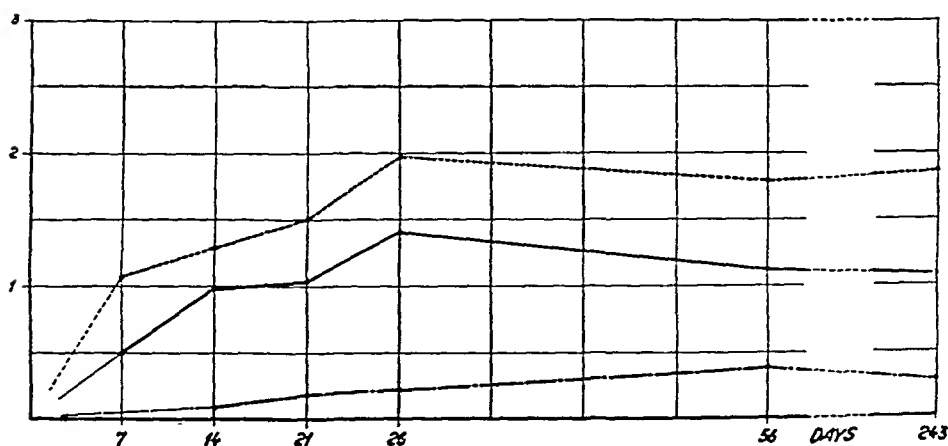


Fig. 9.

Curves showing periosteal formation of new bone, formation of cartilage.



This table, the rest of the material and Fig. 9, page 449, show that the periosteal reaction is visible after a few days, shows rather an even increase during the first 3 or 4 weeks, and then remains fairly constant at from 1.5 to 2.0 during the rest of the observation period. Compared with the radiographic results, it appears to begin earlier and to be, on the whole, less. The former is due to the fact that the osteoid tissue does not produce any shadow, the latter due to the fact that the microscopy shows the thickness of the new-formed periosteal tissue in one plane only, whereas more can be seen on the radiographs. Further, the sections did not always include both the fractured ends.

The formation of *medullary cavities* is part of the development of the periosteal osseous tissue; it depends on the age and thickness of the latter. At first there are only small cavities with loose connective tissue and vessels between the osseous trabeculae. Gradually part of the osseous tissue is resorbed (near the original surface of the bone), and the cavities become larger. In addition, the marrow now contains haematogenous tissue. At the stage of full development a larger cavity is seen, and then a more or less successive transition into small cavities in the superficial layers, which are enclosed externally by a more compact layer of bone. The numerical assessment is 3 for a large cavity, 2 for a medium cavity and 1 for small cavities.

Days	No. of animals	Cavities in the periosteal layer		
		min.	max.	mean
7	7	0.0	0.5	0.07
14	16	0.5	3.0	1.91
21	15	1.0	3.0	2.20
28	57	2.0	3.0	2.74
56	14	0.0	3.0	2.18
243	13	0.0	3.0	2.15

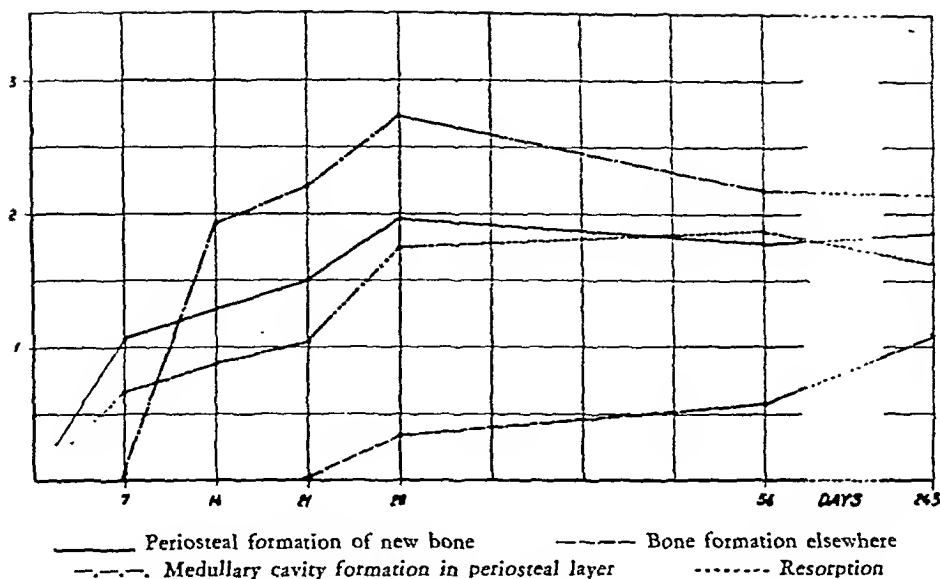


Fig. 10.

Curves showing formation of new bone, resorption, and formation of medullary cavity in the periosteal layer.

These figures and the curve in Fig. 10 show that the formation of the medullary cavities begins in the second week, and reaches its peak in 3 or 4 weeks. It then remains between 2 to  $2\frac{1}{2}$  during the rest of the period of observation.

As the healing of the fracture progresses the tissue on the surface of the periosteal thickening of the bone becomes chondroid; it is then transformed into cartilaginous tissue, which forms the basis of further bone formation. The *formation of cartilage from the periosteum* begins at the most prominent part of the thickened bone close to the fracture surface, and this is the origin of the osseous bridge which will gradually unite the two fragments.

The quantity of cartilaginous tissue may vary within a very wide range. In order to find a fairly reliable basis for the quantitative assessment, sections from a number of fractures with an increasing amount of cartilage were collected and fixed in correct sequence on a glass slide; each fracture

was estimated by comparison with this scale, ranging as usual from 0 to 3.

Days	No. of animals	Formation of cartilage from periosteum		
		min.	max.	mean
7	7	0.5	0.5	0.50
14	15	0.5	2.0	0.97
21	15	0.0	2.0	1.03
28	57	0.0	3.0	1.41
56	14	0.0	2.5	1.11
243	13	0.0	2.5	1.08

This table and the figures and Fig. 9, page 449, show that cartilage formation begins after about a week and increases evenly during the weeks that follow. The apex of the curve occurs at 28 days and coincides with the group with the greatest number of individuals—at 28 days. The curve falls a little during the following week and then remains at about 1. In each case the amount of cartilaginous tissue depends on the growth on the external aspect and the transformation of the tissue into bone from the basal part. When complete bony union develops the cartilaginous tissue decreases; its amount is no exact measure of the healing, but the brisker the proliferation of cartilage, the more rapid the healing of the fracture. In very mobile fractures with only a slight tendency to healing there is, as a rule, little or no cartilage.

If the curves representing periosteal new bone formation and proliferation of cartilage respectively (see Fig. 9, page 449) are compared, they are seen to run almost parallel. The curve representing the periosteal formation of new bone is rather higher, but this might be due to the different assessment.

*Cartilage formation occurs also in other parts of the callus*, though usually only in small quantities. In this connection we do not consider the fibrocartilage in the intermediary callus which can hardly play any decisive role in the actual healing of the fracture. 16 out of 57 cases with cartilage-formation arising elsewhere than from the peri-

osteum occurred in the animals examined on the 28th day. Usually it occurred as a narrow rim of cartilage outside the osseous closing of the medullary cavity. Rarely, cartilage arose from fragments of bone which had remained in continuity with the periosteum. The numerical assessment was made as described above.

Days	No. of animals	Cartilagenformation		
		min.	max.	mean
7	7	0	0.0	0.00
14	13	0	0.5	0.08
21	14	0	0.5	0.18
28	57	0	1.5	0.21
56	13	0	1.0	0.38
243	13	0	1.0	0.27

This table and Fig. 9, page 449, show that the cartilage formation cannot be found before two weeks; it then shows a steady but rather slight increase during the next 6 weeks. After 8 months it is slightly reduced, but the difference is insignificant. This central cartilage formation cannot be regarded as having great importance for healing of the fracture.

Far greater importance must, on the other hand, be attributed to the *bone formation extending beyond the periosteal layer*. By this is meant incipient or complete osseous union between the fragments. As already mentioned, the cartilage on the surface of the primary periosteal thickening proliferates, forming a matrix for an osseous process or, rather, collar, which protrudes towards the other fragment and, by fusion with this, forms the external callus.

This group also includes a few cases in which bone formation was found to extend from the osseous closing of the medullary cavity, joining the osseous tissue from the periosteum. The assessment was made on a rough estimate and on the same principles as in the periosteal formation of new bone.

The actual process of osseous healing only begins after about 3 weeks (Fig. 10, page 451); it increases rather rapidly

Days	No. of animals	min.	Bone formation		mean
			max.		
7	7	0	0.0		0.00
14	15	0	0.0		0.00
21	15	0	0.5		0.03
28	56	0	2.0		0.33
56	13	0	2.0		0.58
243	13	0	3.0		1.08

during the next week and then fairly steadily during the rest of the period of observation.

It has already been mentioned that after about 4 weeks these fractures may feel completely firm. This is due to a primary fibrous healing. At first the *connective tissue* in the callus is a loose, vascularized granulation tissue, but gradually the aseptic inflammation subsides; the tissue becomes richer in collagenous fibrils and poorer in vessels. At last it is completely cicatricial, and in many cases has been transformed into fibrocartilage. In the more mobile fractures the collagenous fibrils often form almost ligamentous strands which are surrounded by loose connective tissue, and run in various directions. The different phases of development of the connective tissue are seen very distinctly in preparations stained by van Gieson-Hansen's staining method.

Loose granulation was assessed as 1, the fibrous tissue still fairly rich in cells as 2, and the tissue which was poor in cells, cicatricial, fibrous or fibrocartilaginous as 3.

Days	No. of animals	min.	Connective tissue of callus		mean
7	7	1.0	1.5		1.40
14	16	1.5	2.0		1.94
21	15	2.0	2.5		2.10
28	56	1.5	3.0		2.70
56	14	2.0	3.0		2.79
243	12	3.0	3.0		3.00

The table and Fig. 8, page 448, shows that after one week the tissue is a granulation tissue, after two weeks it is fibrous

and after four weeks usually cicatricial. In some cases the nature of this tissue determines the firmness of the fracture; thus, fractures may be firm after 4 weeks, though osseous healing must be considered out of the question at this time. On the other hand, it is not a decisive factor, as all the fractures in the last group were assessed at 3, although some of them were still mobile. The maturation of the connective tissue of the callus seems to be mainly determined by the age of the fracture.

Finally, *the resorption of the bone* at the fracture site has also been assessed numerically. If there were only few osteoblasts and lacunae, the resorption was assessed as 1, vigorous resorption, including rarefaction of the cortical layer, as 3, the intermediary stage as 2.

Days	No. of animals	Resorption		
		min.	max.	mean
7	6	0.0	1.0	0.67
14	13	0.5	2.0	0.88
21	13	0.5	1.0	1.04
28	54	0.0	3.0	1.74
56	13	0.5	3.0	1.88
243	13	1.0	3.0	1.62

These figures and the curve in Fig. 10, page 451, are at first a little below those for the periosteal formation of bone, but after the twenty-eighth day they almost coincide with them.

All these numerical assessments are, of course, open to much criticism, and they can hardly represent more than a rough estimate. On the other hand, the detailed analysis gives a better idea of the course of the individual processes of healing and so makes it possible to demonstrate deviations from the usual pictures.

It is striking to see how small a part the endosteal formation of bone plays in the healing of these fractures.

In order to obtain a total exponent of the stage of healing, we have computed the mean figures of all the single assess-

ments in each fracture. The figures of the first three assessments were reserved, e.g. no haemorrhage was assessed as 3, slight haemorrhage as 2 etc., since the extent and amount of haemorrhage, of infiltration, and of cavity decrease with progressing healing.

Days	No. of animals	Total histological assessment		
		min.	max.	mean
2	1	0.00	0.00	0.00
4	2	0.27	0.45	
7	8	0.68	0.89	0.78
9	4	0.95	1.18	
11	5	0.95	1.45	
14	15	1.05	1.64	1.44
16	1	1.00	1.00	
21	15	1.23	2.15	1.65
24	2	1.50	1.56	
28	57	1.40	2.55	1.79
35	11	1.18	2.50	
42	5	1.64	2.27	
49	5	1.50	2.09	
56	14	1.05	2.46	1.97
63	5	1.41	1.82	
64	2	1.50	2.27	
70	5	1.65	2.09	
84	4	1.15	1.94	
94	3	1.40	1.80	
243	13	1.45	2.59	1.98

These figures and the curve, Fig. 11 and 11a show a rapid rise during the first 4 weeks and then a constant level. As was the case for clinical firmness and the radiographic appearances, the standard deviation was large. The method becomes far more cumbrous and time-wasting in the larger experimental series and, as it is the result of many single assessments, becomes more uncertain. Its greatest value lies in its indication of possible deviations, particularly during the first 4 weeks, from the usual picture of healing.

In the preceding pages we have examined the course of healing of a single form of fracture: a transverse fracture through the middle third of the femur in 271 white rats,

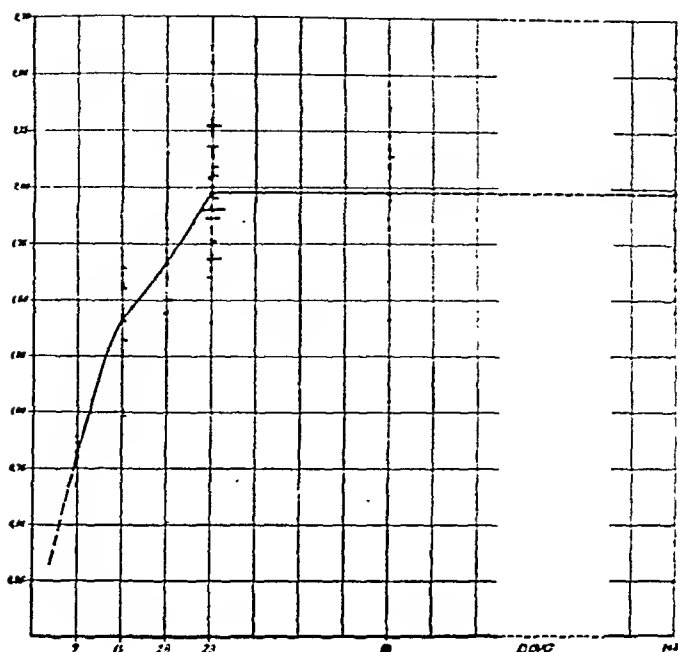


Fig. 11.

Curve showing healing as judged from the histological findings.

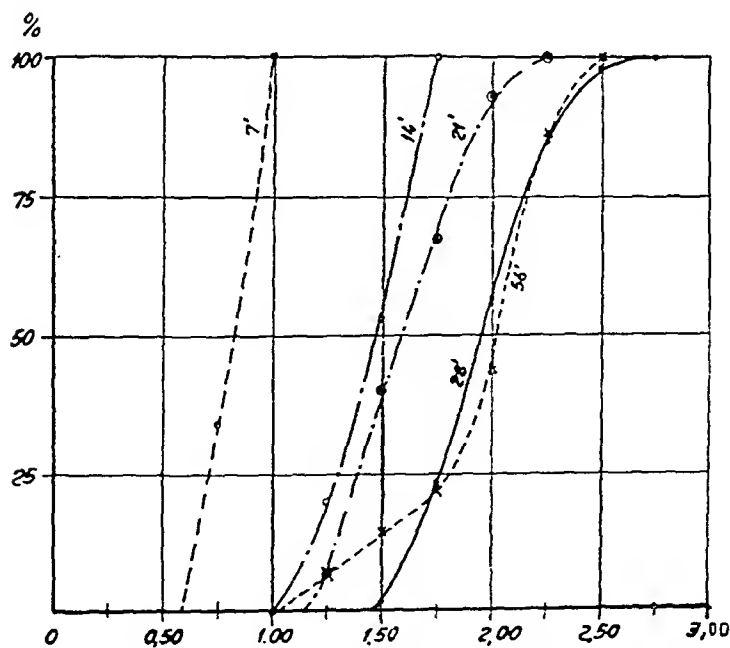


Fig. 11 a.

Cumulative curves showing healing (judged from histological findings) for 7, 14, 21, 28 and 56 days.



aged 4 to 5 months and born at different times of the year. The period of observation varied, the longest being 243 days. The degree of healing was assessed according to the mobility, the radiographic picture and the histological appearances. The mobility is recorded in degrees of movement, and the radiographic picture and histological appearances in grades of 0 to 3. The following mean figures were found:

Days	No. of animals	Mobility	Radiographic appearance		Histology
			periosteal reaction	resorption	
14	44	78°	0.53	0.36	1.44
21	38	53°	0.84	0.76	1.65
28	57	37°	1.14	1.14	1.79
56	51	28°	1.63	1.53	1.97

The figures, which indicate the normal course of healing of these fractures, make it possible to detect any delay or acceleration of healing in any experimental series in which such alterations are sufficiently large.

## II.

### INVESTIGATIONS INTO THE INFLUENCE OF VARIOUS TISSUES ON THE RATE OF HEALING OF FRACTURES

The time required for the healing of a fracture depends on the nature of the fracture, its site, the vascularization, the age of the animal and the accuracy of the reduction. We know that in humans a fracture at a definite site usually heals after such and such a time when the best possible conditions are provided. Experimental attempts to influence the healing of fractures have included, in addition to osteosynthesis, the administration of calcium, tissue transplantation, vitamins, and some of the sex hormones.

Osseous tissue sometimes forms in the cicatricial tissue

after operations on the bladder (*Straus*, 1914, *Neuhof*, 1917, *Phemister*, 1923). This heterotopic bone-formation was shown by *Huggins* (1930) to be brought about by the epithelium of the urinary tract. The examinations reported below started from these observations; the aim was to ascertain whether the factor in the epithelium of the urinary tract which was responsible for the heterotopic bone-formation might also influence the healing of fractures.

The procedure employed in our experiments differed in principle from that employed by *Polletini* (1923), *Levander* (1935, 1938), *Annersten* (1935-1940), and *Bertelsen* (1944). They injected extracts of various tissues intramuscularly, thus producing heterotopic bone-formation or growth of cartilage. As extracting agent they used different liquids, e.g. benzene, alcohol and acid alcohol. They found that extracts of osseous tissue (*Levander* and *Annersten*) and medullary tissue (*Bertelsen*) contained a substance, presumably a lipoid, which promoted heterotopic bone-formation. With this experimental procedure the lesion of the tissue caused by the extracting agent is undoubtedly of some importance as a basis of the bone-formation.

In addition to the epithelium of the bladder we have also tested a number of other tissues and tissue extracts. All the preparations were tested on femoral fractures in white rats aged from 4 to 5 months. Only fractures through the middle third of the femur were used; fractures at a lower level have a shorter healing time. In the first section of the present publication we described the examinations of the course of healing of this kind of fracture in detail. Usually there was a considerable displacement and some of the fractures never became firm, so that the number of subjects in each series had to be comparatively large before any decisive importance could be attributed to possible deviations.

The time at which the treated and untreated controls were compared varies somewhat. The animals were usually killed when the fractures were 4 weeks old, but in some series they were of 2, 3, 5 or 8 weeks' standing.

The comparison with the controls was based mainly on measurements of mobility at the seat of the fracture. For comparison we used partly the mean figure for the mobility, and partly the number of fractures with a maximum of  $15^{\circ}$  or, in larger experimental series, cumulative curves. These figures and those for histological healing agree on the whole with the mobility findings, though they show rather a wide range of variation.

In the preliminary series, rather few subjects were used. If there appeared to be deviations from the normal, the results were usually checked by means of larger series which excluded chance variations. The figures from the controls are shown in parentheses.

### *Epithelium of the Urinary Bladder and Extracts of it.*

The first preparation tested was freshly abraded material from a rats' bladder. Half the quantity removed from the bladder was injected into the fracture site of 18 rats at intervals of two days; the animals were killed after 5 to 24 days. 9 animals, however, had to be excluded as the fracture was in the distal half of the femur. The remaining 9 seemed to show a somewhat better healing than the controls.

A further series was injected with freshly-abraded material from rabbit's bladders. The amount obtained from the bladder of one rabbit was approximately equal to that obtained from four rats' bladders. 10 rats each received an injection of 0.1 cc. of abraded material seven times into the fracture site; they were all killed at the end of two weeks. The healing of the fractures showed the following mean figures: Mobility  $35^{\circ}$  ( $78^{\circ}$ ), periosteal reaction 1.00 (0.53), resorption 0.95 (0.36), histological assessment 1.83 (1.44). Though the experimental series was small, the figures suggest an increased rate of healing.

In order to decide whether this improvement was due to a local or a systemic effect, scrapings from rats' bladders

were injected, in the same dose as in the first experiment, three times a week intramuscularly into the femur of the healthy side. The series comprised 52 animals which were killed at intervals of a week. The period of observation varied from 7 to 35 days. The findings were as follows:

<i>2nd Series</i>				
Days	Range of Mobility	Periosteal reaction	Resorption	Histological assessment
7	102° (110°)	0.65 (0.25)	0.70 (0.00)	0.90 (0.83)
14	78° (78°)	0.78 (0.53)	0.83 (0.36)	1.46 (1.44)
21	50° (53°)	1.00 (0.84)	1.05 (0.76)	1.70 (1.65)
28	57° (37°)	1.05 (1.14)	1.00 (1.14)	1.78 (1.79)
35	37° (33°)	1.23 (1.40)	1.09 (1.42)	1.89 (1.79)

With regard to mobility, the experiment shows no difference. On the other hand, in the first two groups the periosteal reaction and the resorption are rather greater than in the control groups. The histological assessment shows normal figures. On this occasion all the scrapings for injection were prepared at the same time, at the beginning of the experiment, and it is most reasonable to suppose that the poor effect in the later groups is due to autolysis, though the preparation was stored in a refrigerator. The only conclusion that can be drawn from this experiment is that the active agent does not keep well in a suspension of cells.

As it was difficult to obtain the epithelium of rats' and rabbits' bladders in sufficiently large quantities, a preparation was made from epithelial scrapings from ox bladders. 31 fresh bladders, sent on ice from the slaughter-house, yielded 35 gm. of abraded epithelium. 15 gm. were suspended in 100 cc. of physiological saline. 2 cc. of the suspension was then injected into the fracture site three times a week in 8 rats; the animals were killed at the end of 4 weeks. The following figures were found: Mobility 61° (37°), periosteal reaction 1.00 (1.14), resorption 0.75 (1.14), histological assessment 1.57 (1.79). Thus all the results were less good than in the series of controls.

The remaining 20 gm. of abraded epithelium were extracted for 48 hours in 50 cc. of physiological saline solution and

centrifuged, and the sediment was suspended in 50 cc. of physiological saline solution. The aqueous extract was tested on 8 animals, the sediment on 10; 0.2 cc. being injected twice a week into the fracture site. In 4 weeks the figures were as follows:

Liquid: Mobil.	84°	periost. react.	0.81	resorp.	0.63	histol.	1.40
Sediment: „	38°	„	1.42	„	1.00	„	1.67
Control: „	37°	„	1.14	„	1.14	„	1.79

The number of animals was small, but the findings suggest that there may be an active agent, which is not soluble in physiological saline solution. All the fractures in the first series had a mobility of more than 15°, while in 4 out of 10 fractures of the second series 15° was the maximum range.

A double dose of the sediment was then injected into the healthy side; the experimental conditions were otherwise the same. The number of subjects was 10; the figures were as follows: Mobility 36° (37°), periosteal reaction 1.55 (1.14), resorption 1.50 (1.14), histological assessment 1.86 (1.79). Thus the result was better than when the injection was made into the fracture site.

In another experimental series 15 gm. of abraded epithelium of ox bladder were extracted for 48 hours with 100 cc. of distilled water in an ice-box, after which sodium chloride was added to give a concentration of 0.9 per cent. After centrifuging 0.2 cc. of the aqueous extract was injected into 7 rats twice a week for 4 weeks. The injection was made into the seat of the fracture itself. The figures for healing were as follows: Mobility 79° (37°), periosteal reaction 1.00 (1.14), resorption 0.86 (1.14), histological assessment 1.37 (1.79), i.e. decidedly poorer than the normal.

The cellular remains were suspended in 100 cc. of physiological saline solution, and tested on 6 rats under the same experimental conditions. The result showed no acceleration of the healing after 28 days. The figures were: Mobility 58° (37°), periosteal reaction 1.33 (1.14), resorption 0.92 (1.14), histological assessment 1.85 (1.79).

Another preparation of epithelium of ox bladders was made by washing the epithelium abraded from 100 bladders three times in physiological saline solution and suspending 30 gm. in 100 cc. of saline solution. This preparation, which was thus twice as concentrated as the former, was kept for a fortnight in sealed ampoules and then tested on 32 rats. 12 animals were given 5 injections of 0.2 cc. into the healthy side and were killed after a fortnight. The figures show improved healing. The following mean figures were obtained: Mobility  $54^{\circ}$  ( $78^{\circ}$ ), periosteal reaction 1.12 (0.53), resorption 1.00 (0.36), histological assessment 1.73 (1.44). 11 subjects were treated for 21 days with 8 injections of 0.2 cc. The figures were as follows: Mobility  $53^{\circ}$  ( $53^{\circ}$ ), periosteal reaction 1.32 (0.84), resorption 1.23 (0.76), histological assessment 1.81 (1.65). After 4 weeks the figures relating to the remaining 9 animals, which had been given 11 injections were as follows: Mobility  $50^{\circ}$  ( $37^{\circ}$ ), periosteal reaction 1.06 (1.14), resorption 1.06 (1.14), histological assessment 1.70 (1.79). These three series show that in the first series the preparation was active 4 weeks after its preparation. In the second series, only the later figures were somewhat increased. In the third series all the figures were lower than those in the controls. Abscesses were found at the site of injection in several cases of this series. There was no bone formation at the site of injection.

In order to ascertain whether the abraded epithelium might possibly keep better in the form of powder, part of it was dessicated at  $42^{\circ}$  C. immediately after preparation and two months later it was suspended in physiological saline solution. It was tested in 10 animals, 0.2 cc. being injected into the healthy side. After a fortnight the figures were as follows: Mobility  $104^{\circ}$  ( $78^{\circ}$ ), periosteal reaction 1.00 (0.53), resorption 0.95 (0.36), histological assessment 0.67 (1.44). The last figures are certainly higher than the normal, but the firmness was decidedly less.

Another portion of the abraded epithelium was boiled for half an hour and then stored in ampoules. This preparation

was tested in 10 animals with 8 injections of 0.2 cc. injected during 3 weeks into the healthy side. The results correspond with the normal, and were as follows: Mobility  $88^{\circ}$  ( $53^{\circ}$ ), periosteal reaction 0.90 (0.84), resorption 0.85 (0.76), histological assessment 1.64 (1.65). This seems to suggest that the active agent was not thermostable.

The preceding experiments suggest that the epithelial cells of the bladder (in rats, rabbits and oxen) contain a substance which promotes the healing of fractures. This substance does not keep very well in the cells; it is presumably thermolabile and is insoluble in water. In the fresh state it exerts both a local and a resorptive action, and seems to be associated with the solid constituents of the cell body.

In order to avoid the possibility of a local action on the fracture, the preparations were injected intramuscularly into the femur of the healthy side in all the following experiments.

In the following experiment the possibility of extracting the active agent with alcohol was investigated. 25 cc. of fresh epithelium abraded from ox bladders was washed in physiological saline solution, suspended in 100 cc. of 70 per cent alcohol and extracted for one hour while being shaken. After centrifugation the alcoholic phase was mixed with 25 cc. of physiological saline and evaporated in a vacuum to 25 cc. This preparation was tested in 10 rats, 0.3 cc. being injected 9 times in the course of 3 weeks. The sediment from the extraction was also tested in 10 rats, 0.2 cc. being injected 4 times in the course of two weeks. The results obtained with the alcoholic extract were: Mobility  $61^{\circ}$  ( $53^{\circ}$ ), periosteal reaction 1.40 (0.84), resorption 1.35 (0.76), histological assessment 1.81 (1.65). For the residue the figures were as follows: Mobility  $85^{\circ}$  ( $78^{\circ}$ ), periosteal reaction 1.10 (0.53), resorption 0.95 (0.36), histological assessment 1.64 (1.44). In both series the firmness was on the average a little less than the normal, but in the first series the mobility was below  $45^{\circ}$  in 70 per

cent (normal 47 per cent), and in the second series in 40 per cent (normal 14 per cent). As this experiment, without showing anything definite, pointed in the direction of improved healing after injection of the alcoholic extract, another and more concentrated preparation was made by extracting the abraded epithelium of 25 ox bladders for 48 hours in 400 cc. of 70 per cent alcohol and separating by centrifugation. The alcohol was evaporated in a vacuum at 35° C. to about 75 cc., and this solution was kept in a refrigerator till the next day. During the evaporation, minute precipitations appeared in the liquid, and next day a sediment had collected which was separated by centrifugation and suspended in physiological saline solution up to 75 cc. This preparation was tested in 11 rats, each being given 12 injections of 0.2 cc. After 4 weeks the following results were obtained: Mobility 21° (37°), periosteal reaction 1.73 (1.14), resorption 1.86 (1.14), histological assessment 1.92 (1.79). This result is decidedly better than the normal, particularly considering that the mean figure relating to mobility is normally 28° after 56 days. Only one of the fractures in this experimental series had a mobility exceeding 35°, and in 73 per cent the mobility was less than 15° (26 per cent in the controls).

The clear aqueous phase from the centrifugation was tested in 11 rats with the same arrangement of the experiment. The figures were as follows: Mobility 37° (37°), periosteal reaction 1.27 (1.14), resorption 1.32 (1.14), histological assessment 1.80 (1.79). This result stresses the fact that the active agent had been extracted with alcohol.

The keeping qualities of suspensions of the substance extracted with alcohol were then examined after the preparation had been kept in a refrigerator for 1½ months. 10 rats were given a double dose, and, after 4 weeks, showed the following figures: Mobility 28° (37°), periosteal reaction 1.62 (1.14), resorption 1.46 (1.14), histological assessment 1.88 (1.79). The mobility of half the number of fractures was less than 15° as compared with the normal 26 per cent. Thus there was still some effect, though it was rather less than before.



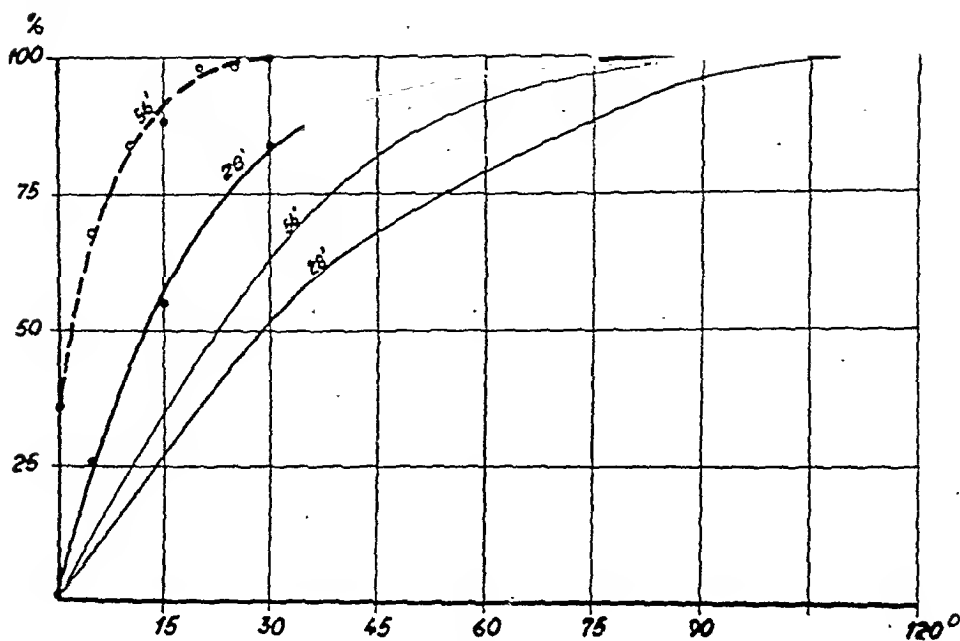


Fig. 12.

Cumulative curves showing the effect of the lecithin fraction from the epithelium of the urinary bladder after 28 and 56 days.

(The thin curves are controls).

After the same period half a dose was tested in 12 subjects. The figures showed no definite deviation from the normal.

The next experiment comprised the testing of four preparations which had been made as follows: Epithelium abraded from ox bladders was washed repeatedly in physiological saline solution. The sediment was extracted with 70 per cent alcohol for about 24 hours, after which the alcohol was evaporated at a temperature below 40° C. The alcohol was extracted with ether and, after admixture of acetone, greasy yellow-brown masses were precipitated; these were suspended before use by shaking with distilled water. A 1 per cent suspension was used in the first experiment and 2 per cent suspensions in the others. The results were as follows:

The mean figures for the last three preparations, which were of the same strength, are as follows with regard to mobility and radiographic assessment: Number of subjects 69;

Prep.	No. of animals	Mobility	Periosteal reaction	Resorp- tion	Hist. asseess- ment	Max. mo- bility 15°
8/13 (1 %)	12	40°	1.37	1.25	1.92	42 %
7/90 (2 %)	12	24°	1.58	1.37	1.83	58 %
8/24 (2 %)	30	12°	1.30	1.25		67 %
8/32 (2 %)	27	25°	0.83	0.89		41 %
Controls	57	37°	1.14	1.14	1.79	26 %

mobility 19°; periosteal reaction 1.17; resorption 1.13; maximum mobility 15° in 55 per cent. When these figures are compared with the control figures, it is clear that the firmness is greatly increased. On the other hand, the reaction seen in the radiographs is not increased and, consequently, the firmness must be supposed to be due largely to fibrous healing. The cumulative curve for the mobility of the last three specimens showed a marked displacement to the left (Fig. 12, page 466).

As the active agent might exert its effect on the connective tissue only, and perhaps even delay the actual healing, preparation 8/32 was injected in doses as stated above for 4 weeks, and the animals were then left untreated for another 4 weeks. The result was as follows:

Prep.	No. of animals	Mobility	Periosteal reaction	Resorp- tion	% of animals with max. mo- bility 15°
8/32 (2 %)	50	7°	2.07	1.95	88 %
Controls	43	28°	1.63	1.53	42 %

This result confirmed the previous findings and also showed that the increased fibrous firmness was followed by osseous consolidation. The same appears from the cumulative curves representing periosteal reaction and resorption (Fig. 13, page 468).

The aqueous phase from the alcohol extract from preparation 7/90 was injected into 11 animals in injections of 0.2 cc. 3 times a week for 4 weeks with the following results: Mobility 36° (37°), periosteal reaction 1.27 (1.14), resorp-

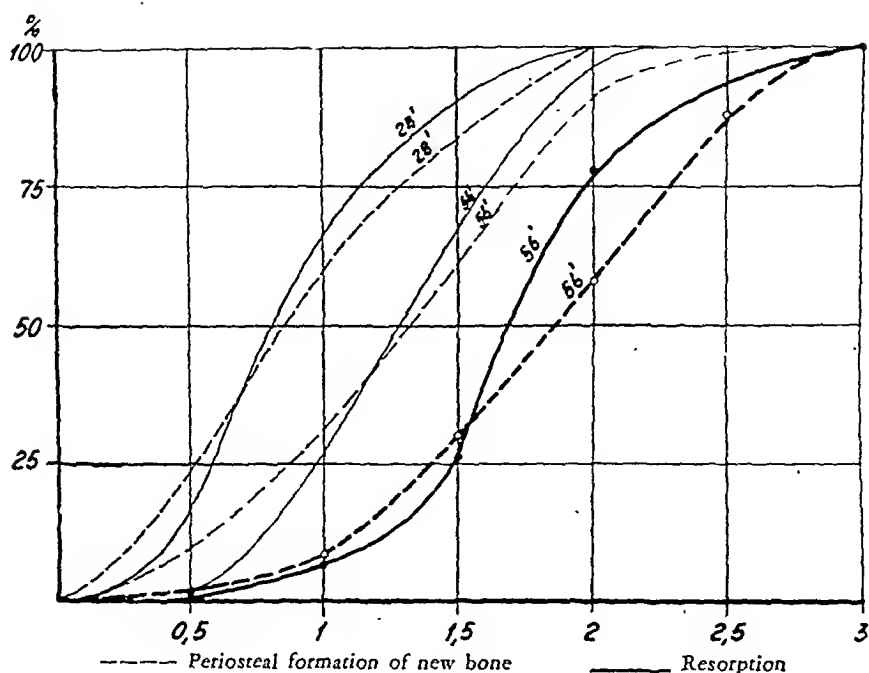


Fig. 13.

The effect of the lecithin fraction from the epithelium of the bladder on the healing of fractures as judged from the radiographs.  
(The thin curves are controls).

tion 1.41 (1.14), histological assessment 1.92 (1.79). This did not seem to produce any great effect.

The fats which were present in the ether extract but were not precipitated by acetone were tested in two series. The fats were dissolved in oil, and 0.2 cc. was injected three times a week for 4 weeks:

Prep.	No. of animals	Mobility	Periosteal reaction	Resorp- tion	Max. mo- bility 15°
8/13	24	37°	1.44	1.21	29 %
8/24	30	23°	1.13	1.17	40 %
Controls	57	37°	1.14	1.14	29 %

The greater part of the active agent seems to be precipitated by acetone, and thus accompanies the lecithin fraction.

As an additional control of the extraction experiments stated above, 10 gm. of crude lipid was extracted from all

the tissues of the bladder. This crude lipoid was fractionated<sup>1</sup> into sphingomyelin (1.48 gm.), cephalin (2.3 gm.), lecithin (2.6 gm.) and a fraction presumably consisting of cerebro-sides (0.4 gm.).

	No. of animals	Mobility	Periosteal reaction	Resorp- tion	Max. mo- bility 15°
Total bladder extract	25	33°	1.36	1.34	44 %
Sphingomyelin .....	15	34°	1.03	1.07	20 %
Cerebrosides (?) .....	15	37°	1.20	1.10	27 %
Cephalin .....	15	51°	1.20	1.17	20 %
Lecithin phase .....	26	28°	1.27	1.21	54 %
Controls .....	57	37°	1.14	1.14	26 %

Even though the deviation was less than when preparations made of epithelium of the bladder only were used, the mean figures relating to mobility, and in particular the percentage of fractures with a maximum mobility of 15°, still show that the active factor is present in the lecithin fraction. Radiography did not reveal any great deviation from the normal in these experiments either.

Thus the final result of these investigations into the effect of epithelium of the bladder on the healing of fractures is that the epithelial cells contain a substance of resorptive action which accelerates the healing of fractures (about 100 per cent in the experimental material), and accompanies the lecithin fraction in the course of preparation. The increased firmness seems first to depend on fibrous healing, followed by osseous healing. Thus the substance is not actually osteogenetic. Bone formation was never found at the sites of puncture.

### *Sperm.*

In view of the results of the influence of epithelium of the bladder on the healing of fractures described in the preceding pages, experiments were made with injection of spermatozoa. The preparation employed was a suspension of fresh sperm-

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<sup>1</sup> The fractionation was kindly undertaken by Frank Lundquist, civil engineer, M.Sc.

atozoa of bulls (supplied by the Royal Veterinary and Agricultural College); counts showed about 59,000 spermatozoa per cubic millimetre. 0.1 cc. of the suspension was injected into the fracture site twice a week for 3 weeks. This series comprised 10 subjects, and gave the following results: Mobility  $84^{\circ}$  ( $53^{\circ}$ ), periosteal reaction 1.15 (0.84), resorption 1.00 (0.76), histological assessment 1.24 (1.65). Thus there was definitely less firmness, even though the periosteal reaction was increased.

### *Medullary Tissue.*

As previous examinations had shown that the epithelial cells of the bladder contained a substance promoting the healing of fractures, it was natural to examine whether bone marrow, the site of maturation of the cells of the blood, would also influence the healing of fractures. The marrow was aspirated from the bones of 5 rats, and immediately suspended in physiological saline solution. It was injected 5 times in two weeks into the healthy limb of 9 rats. The result was as follows: Mobility  $95^{\circ}$  ( $78^{\circ}$ ), periosteal reaction 1.00 (0.53), resorption 0.89 (0.36), histological assessment 1.46 (1.44). In this case, too, there was less firmness, though both the periosteal reaction and resorption were increased.

### *Extract of Brain Tissue.*

The active agent in the epithelium of the bladder was obtained from the lecithin fraction. A similar preparation of rats' brains was made. It contained 1.50 per cent of lecithin in physiological saline solution, and 0.3 cc. was injected twice a week for 4 weeks into the healthy leg of 12 rats with the following: Mobility  $25^{\circ}$  ( $37^{\circ}$ ), periosteal reaction 1.33 (1.14), resorption 1.25 (1.14), histological assessment 1.96 (1.79); this suggests some effect, though hardly so great as that exerted by preparations of epithelium of the bladder. 33 per cent of the animals treated had a maximum mobility of  $15^{\circ}$

(normal 26 per cent) and 83 per cent had a maximum mobility of  $45^{\circ}$  (normal  $65^{\circ}$  per cent).

Choline chloride, which is present in lecithin, was also tested, 0.3 cc. of 1.5 per cent solution in physiological saline was injected into 12 rats twice a week for 4 weeks; the following figures were obtained: Mobility  $34^{\circ}$  ( $37^{\circ}$ ), periosteal reaction 1.29 (1.14), resorption 1.33 (1.14), histological assessment 1.98 (1.79); thus there was no change in the healing of the fractures.

#### *Extract of Liver Tissue.*

The livers of 25 rats were extracted with alcohol and ether and precipitated with acetone; 0.2 cc. of a 2 per cent suspension of this preparation in physiological saline solution was injected 11 times in the course of 4 weeks into 12 rats. The result showed a distinct improvement of the healing: Mobility  $17^{\circ}$  ( $37^{\circ}$ ), periosteal reaction 1.62 (1.14), resorption 1.50 (1.14). In 54 per cent of the fractures the maximum mobility was  $15^{\circ}$  (normal 26 per cent). Pig's liver was prepared in the same way and injected in the same doses into 32 rats; the results were: Mobility  $28^{\circ}$  ( $37^{\circ}$ ), periosteal reaction 1.28 (1.14), resorption 1.37 (1.14). 34 per cent had a maximum mobility of  $15^{\circ}$  (normal 26 per cent). Thus the results were less marked than in the preceding experiment, though the healing had been distinctly accelerated. A mobility of  $28^{\circ}$  normally corresponds to 8 weeks' healing time.

#### *Extract of Stomach Tissue.*

Hog's stomachs, which are otherwise used for the production of ventriculin, were also prepared in the same way, and 0.2 cc. of a 2 per cent suspension in physiological saline was injected 11 times into 22 rats. All the figures were poorer than the normal figures of healing.

In conclusion it may be mentioned that extracts of blood (400 cc.) and striated muscle were also prepared, but in both cases the outcome was minimal.

*Comment.*

The healing of a fracture is made up of a number of component processes, each of which depends on a number of factors. The healing depends on the nature, localisation and reduction of the fracture. The actual healing process, which consists in the formation of an osseous bridgelike union between the fractured ends of the bone, follows quite a definite course, but is influenced by the different factors mentioned above. In the present work the possibility of influencing the course of healing by injections of tissue or tissue extracts has been investigated.

The healing of one particular type of fracture, fracture of the diaphysis of the femur of white rats, was analysed quantitatively and in detail. It appeared that the course of healing could be assessed numerically by testing the firmness of the fracture and by radiographic and histological examination. The healing is best represented by assessment of the degree of firmness. The radiographic appearances approximately reflect the course of healing, but may not follow it exactly. The histological assessment of the healing is useful during the first four weeks, but a close analysis of the single components showed that it is less accurate than the other two methods.

A number of tissues and tissue extracts were tested. It was found that the epithelium of the bladder contained a substance which was insoluble in water, but was soluble in 70 per cent alcohol and ether; it was precipitated by acetone. This substance had a resorptive action; it did not cause any local irritation. It gave a negative ninhydrin reaction.

It is presumably a lipoid; it accompanies the lecithin fraction and seems to be thermostable. It does not seem to be osteogenetic in the true sense of the word, since an increased firmness of the fractures is found without corresponding radiographic changes, but increased firmness provides better conditions for healing. The effect seems to depend on a primary fibrous healing, and its action seems to be mainly

a more rapid ripening of the connective tissue. That the epithelium of the bladder should contain a factor having a specific osteogenetic effect is hardly probable. It seems more reasonable to suppose that the rapidly growing epithelium of the bladder contains a substance which is of importance to the growth and ripening of cells. Correspondingly, no heterogeneous formation of bone was ever found after injection of this extract. The factor caused the percentage of healing to rise from 26 to 55 (after 4 weeks).

Extracts of other organs were tested by the same technique. Liver extracts gave varying results. An extract of homologous hepatic tissue caused a rise of the percentage of healing from 26 to 54, whereas heterologous liver extracts were of doubtful effect. An extract of homologous brain tissue did not produce any certain improvement in spite of the high lecithin content of the brain. This suggests that the active factor either is only a fraction of lecithin, or accompanies the lecithin fraction. Heterologous stomach extract had no effect, and heterologous extracts of blood and striated muscle were so poor that they were not tested.

#### SUMMARY

The course of healing of diaphyseal fractures of the femur in 271 rats was examined. It was estimated by assessing the degree of firmness and the radiographic and histological appearances.

Employing this normal material as controls, the influence of a number of tissues and tissue extracts on the healing of fractures was examined. The epithelium of the urinary bladder contains a factor which accompanies the lecithin fraction; this factor has a resorptive effect, and causes the percentage of healing after 4 weeks to rise from 26 to 55. Extracts of liver tissue produced somewhat varying results; extracts of heterologous brain tissue had no certain effect, and extracts of heterologous stomach tissue had no effect at all.



## RESUME

Le cours de la guérison de fractures diaphysaires du fémur a été examiné dans 271 cas. Il a été évalué en établissant le degré de fermeté de la fracture et en se basant sur les aspects histologiques et radiographiques.

Utilisant ce matériel normal à titre de contrôle, l'influence d'un certain nombre de tissus et d'extraits de tissus sur la guérison des fractures a été examinée. L'épithélium de la vessie contient un facteur qui accompagne la lécithine ; ce facteur a un effet de résorption et fait monter au bout de quatre semaines le pourcentage de guérison de 26 à 55. L'extrait du tissu du foie produit des résultats tant soit peu durables et les extraits de tissu hétérogène du cerveau n'ont pas d'effet certain, ceux de tissu hétérogène d'estomac absolument aucun effet.

## ZUSAMMENFASSUNG

Der Heilungsverlauf von Diaphysenbrüchen des Femurs in 271 Ratten wurde untersucht. Er wurde beurteilt nach dem Grade der Festigkeit des Bruches und den histologischen und röntgenologischen Bildern.

Indem man dieses normale Material zur Kontrolle verwendete, wurde der Einfluss einer Anzahl von Geweben und Gewebsextrakten auf die Bruchheilung untersucht. Das Epithel der Harnblase enthält einen Faktor, der mit der Lecithinfraktion verbunden ist. Dieser Faktor hat eine resorptive Wirkung und verursacht eine Erhöhung des Heilungsprozentsatzes nach 4 Wochen von 26 zu 55. Lebergewebsextrakte geben einigermassen variierende Resultate, Extrakte von heterologem Gehirngewebe hatten keinen sicheren Effekt und Extrakt von heterologem Magengewebe hatten überhaupt keinen Effekt.

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## SOME EXPERIENCES WITH A BONE BANK

By

LENNART HULT, M.D.

Transplantation of bone is a frequent procedure in orthopaedic surgery. Hitherto, autogenous transplantations have been usual, bone being taken from the same individual, usually from a tibia or iliac crest. The disadvantage of this form of transplantation is the longer and more severe operation, and the rather lengthy post-operative inconvenience from the donor site. In homogenous grafting, bone is transplanted from one individual to another. A successful operation of this kind was performed as early as 1878 by MacEwen, and has since been described by a number of authors, for both experimental animals and humans. However, a more systematic use of homogenous transplantation has only come into use in the last 2-3 years. In 1947, publications were issued from two different hospitals in New York, reporting good results of 100 operations of this type of bone grafting. The novelty lay in the fact that the transplant of bone had been preserved for varying periods in a frozen condition. This method of storage makes it possible to have bone grafts always available for use. A bone bank consists of bone removed at operations and stored in a sterile frozen condition for later use.

The organisation of a bone bank is based on the following facts and assumptions:

- 1) Homogenous and autogenous bone are equally useful; in both cases the graft dies, but its presence acts on the surrounding connective-tissue in such a way that it is transformed into bone by metaplasia. Thus, both act in the same way as the cell-free alcohol-extract of bone with which *Levander* and

others were able to induce bone formation in the muscles of rabbits. As the vessels accompanied by connective tissue grow into the Haversian canals of the graft, bone is formed and gradually the entire graft is reconstructed to form new living bone by "creeping substitution".

2) Neither the blood group nor the Rh factor are of significance, and no attention need be paid to them.

3) Bone can be stored in sterile containers in an ordinary refrigerator ( $+ 2$ – $+ 6^{\circ}$ ) for three weeks, and at  $- 15$ – $- 25^{\circ}$  indefinitely.

4) The donor must be controlled. Thus, his WR must be negative. Spirochaeta stored at  $- 78^{\circ}$  were found to be still virulent after 4 months. He should have no history of infection for some time before the graft is taken. His sedimentation rate should preferably be normal.

5) Sulphonamides interfere with the calcification process.

6) The bone grafts should be stored dry. Carrel reported before 1920 that transplanted tissues e.g. bone, skin or other substances stored in Ringer's solution either do not heal or heal less well than when stored dry. In accordance with *Levander's* tests, this might be due to extraction of the osteogenetic active substance by the Ringer's solution.

7) Cortical bone is the best for stability, spongiosa for osteogenesis.

In transplantation a bone graft has a threefold function.

- a) It gives stability.
- b) It stimulates osteogenesis.
- c) It serves as a matrix for the bone formation which assumes the shape and extent of the graft.

At the Orthopedic Clinic of the Karolinska Institute a bone bank was instituted in September 1948. Some of the bone is supplied by the clinic of thoracic surgery and consists chiefly of ribs from operations in non-infectious cases; some, consisting mostly of ribs and vertebral spinous processes, by the neurosurgical clinics; and some by the Orthopaedic Clinic, from amputations and other operations. Bone which is to be stored is divested of all its soft parts and placed in an ordinary

preserving-jar immediately after the operation. The jar has been previously sealed and sterilised in an autoclave. After receiving the bone, it is re-sealed and transferred to a deep freezer, where the temperature is kept at  $\div 13\div 15^{\circ}$ . Before use the jar is removed to room-temperature for 30-60 minutes.

We have now used bone-bank bone from 75 different bone donors in 48 operations, with apparently good results in every case. In 4 cases there was a slight wound-infection, which scarcely had any connection with the transplant. As far as can be judged from an observation period of not less than four months, the healing can be said to have taken place in a normal way. Bone from the bone bank has mainly been used for spinal fusions. 12 were cases of scoliosis and 27 of lumbar disc-degeneration. There were also 3 cases of arthrodesis of the hip; 3 of pseudarthrosis, 1 of which had a large femoral cyst; 1 shelf-operation for the hip, and 1 of arthrodesis of the wrist. The bone was generally cut into small chips, partly to fill out all the recesses and partly to enlarge its surface, as, according to the above, bone formation proceeds from the surface of the graft. The transplant was used whole only when aiming to obtain stability; it was then usually taken from the femur or tibia. In these cases it was generally surrounded by small pieces of spongiosa bone.

When the containers were opened, small pieces of bone were cultured as controls. 11 samples, from 68 donors, gave a sparse growth of non-pathogenic or doubtful pathogenic staphylococci, and 1 a growth of pathogenic streptococci. Bone giving a positive culture was used in 9 cases without any apparent complications of any kind. Of the 4 cases in which slight infection occurred, the culture of the graft was positive in 1. The remaining 8 cases receiving grafts with positive culture showed perfect healing, including the case which received the bone with streptococci. The longest period of bone-storage before use was 67 days.

In summarising, it can be said that our experience with the bone bank has been very satisfactory; its use reduces the time and the severity of operation, and this is essential.

Operations which one would not otherwise dare attempt can be performed, and, as more bone is available than the patient himself could provide, both a more certain osteogenesis and a more stable osteosynthesis is obtained. Probably bone taken from a corpse, or even from an animal, might be used with equally good results, but, as our supply has hitherto been good, this question has not yet arisen.

### SUMMARY

The theoretical and practical requirements of a bone bank were discussed. Bone can be kept sterile at  $\div 15^{\circ}\text{C}$  for practically as long as one likes. At the Orthopaedic Clinic of the Karolinska Institute bone from the bone bank, taken from 75 different donors, has been used for 48 operations, with good results in all cases. The use of stored bone means that in many cases there is a considerable reduction in the severity of the operation, and it is recommended for this reason.

### RESUME

Discussion sur les conditions théoriques et pratiques de la constitution d'un stock d'os. On peut maintenir la stérilisation des os aussi longtemps qu'on le désire en les conservant à une température de moins  $15^{\circ}$ . A la Clinique Orthopédique de l'Institut Karolinska, des os provenant de stocks fournis par 75 différents donateurs, ont été utilisés dans 48 opérations avec de bons résultats dans tous les cas. L'emploi d'os stockés signifie que l'on peut dans beaucoup de cas réduire considérablement la gravité de l'opération est c'est pourquoi on le recommande.

### ZUSAMMENFASSUNG

Die theoretischen und praktischen Forderungen einer Knochenaufbewahrungsstelle (Knochenbank) werden besprochen. Bei  $\div 15$  Grad Celsius kann man Knochen steril bewahren so

lange als man wünscht. An der Orthopädischen Klinik des Karolinska Institutes wurde Knochen von der Knochenbank verwendet, der von 75 verschiedenen Spendern entnommen war. Dies geschah in 48 Operationen und die Resultate waren gut in allen Fällen. Der Gebrauch von aufbewahrtem Knochen bedeutet in vielen Fällen eine beträchtliche Verringerung der Schwere der Operation und wird deshalb anbefohlen.

## ON TRANSPLANTATION OF CANCELLOUS BONE FROM THE ILIAC CREST

BY

ARNE BÉRTELSEN and EIVIN HASNER

### INTRODUCTION

The treatment of haematogenous and fracture osteomyelitis, pseudarthroses, facial skeletal defects and other bony lesions has always aroused considerable interest. Numerous clinical and experimental papers on these subjects have appeared.

Although there are still unsolved problems and divergent opinions on the subject, it may generally be said that good results depend mainly on the radical removal of all diseased tissue, adequate skin and soft tissue covering and transplantation of bone to the defect.

Living autogenous bone transplants can be classified in the following way:

- 1) transplants of whole bone (*Ollier* 1860, *Eloesser* 1920, *Sauerbruch* 1922, *Graham & Riordan* 1948, *van Nes* 1948).
- 2) osteo-periostal transplants (*Delagenière* 1921, *Mathieu* 1926, *Campbell* 1931).
- 3) transplant of cortical bone with or without periosteum, usually taken from the tibial diaphysis (*Maragliano* 1919, *Albee* 1913, *Bristow* 1934).
- 4) cortical bone chips (*McEven* 1912, *Osgood* 1926, *Bull* 1928).
- 5) block-grafts of cancellous bone, usually taken from the



iliac crest (*Lindemann* 1916, *Partsch* 1922, *Putti* 1929, *Albee* 1929, *Hybinette* 1932, *Lance* 1926).

6) block-grafts of cancellous bone + chips, usually taken from the iliac crest, or, more rarely, from the greater trochanter (*Partsch* 1922, *Schumm* 1929, *Matti* 1932, 1936, 1939, *Henderson* 1933, *Mowlem* 1941-44).

7) cortical block transplants + cancellous chips.

Only the main methods and not all the variations in technique are mentioned. Thus the os novum technique, cortico-cancellous sliding grafts, and other modifications are not grouped separately.

In this paper the indications for and the results of the two last methods, particularly that of cancellous chip grafts from the ilium are discussed.

#### *Earlier Clinical Investigations.*

Block grafts of cancellous iliac bone are generally said to have been introduced by *Lindemann* in 1926. About the same time *Gillies* and his co-workers began to use block grafts for the treatment of *mandibular defects*. In 1927 *Partsch* reported one case of mandibular defect treated with a cancellous graft from the ilium, and in 1927 one further case. In 1932 *Matti* reported that he had started using cancellous grafts during the first world war. *Risdon* recommended their use in 1922, *Ivy & Epes* in 1927—all for mandibular defects.

In recent years there have been many publications which have generally confirmed the value of cancellous chip grafts for the mandible, e.g. *Cuthbert* (1944), *Converse* (1945), *Blocker and Weis* (1946), *Clarkson, Wilson & Lawrie* (1946), *Blocker* (1948), *Blocker & Stout* (1949).

In 1932 *Matti* published an experimental work on transplantation of cancellous bone from the pelvis, the trochanter, and the femoral diaphysis. In 1936, in a clinical work on the treatment of pseudarthroses, he reported the use of cancellous bone from the trochanter, and in 1939, in a paper on arthrodesis of the hip, the use of cancellous bone from the iliac crest.

Although plastic surgeons have agreed from the beginning on the value of cancellous bone grafts, *McIndoe*, in 1941, was the first to stress that cancellous bone from the ilium is the most suitable for *plastic operations* on the face and skull. He prefers block grafts.

The indications for purely plastic grafting operations have been described by *Stuart Gordon* (1946) and *Macomber* (1946). Both authors

believe that autogenous cancellous chips give better results than other material (cartilage, allo-transplants, and bank-bone).

Especially due to *Mowlem's* papers (1941-44) the indications for the use of cancellous bone chips were widened. In recent years they have been increasingly used in surgery of the jaw, in plastic surgery, and in limb surgery and orthopaedics.

In the treatment of *osteomyelitis*, whether haematogenous or following fractures and gunshot-wounds, all writers stress the importance of radical removal of all diseased tissues, and some also call attention to the importance of a solid skin and soft-tissue covering. In all series the percentage of primary healing has been about 90. (*Coleman, Bateman, Dale & Starr* 1946, *Abbott, Bost, Schottstaedt, Stern & McCorkle* 1946, *Carpenter, Rosenfeld & Mech* 1946, *Higgs* 1946, *Moon* 1944, *Robertson & Barron* 1946).

In 1948 *Hogeman* reported the first Scandinavian series of nine cases of whom seven had osteitis or osteomyelitis, and two pseudarthrosis. One had been observed for eleven months, two for six months, and the rest for less than three months. In two cases with partial skin necrosis the granulating surface was grafted three to four weeks after the first operation. There had so far been no evidence of relapse.

*Key* in 1943, and *Dick* in 1948 used iliac chips for *pseudarthroses*, and for arthrodesis of various joints, especially where stability could be obtained without the use of a cortical graft. *Dick* stresses that any correction of the position must be performed early, because by the fourteenth day union is often so far advanced that correction is difficult.

*Higgs* (1946) and *Bishop, Stauffer & Swenson* (1947) prefer to combine cortical tibial grafts with ilium chips in the treatment of pseudarthroses. *Higgs* used this combination in 40 out of 60 cases, and found that healing occurred twice as fast as when cortical transplants were used alone.

For pseudarthroses *Horwitz & Lambert* (1947) prefer to combine iliac grafts with a Lane's plate or vitallium screws, since he found that bone grafts when used alone gave 83 % union, and when combined with fixation material gave 90 % union. In these views they differ from the majority of authors, who generally agree that, as far as possible, it is best to use bone grafts alone, in particular cancellous bone grafts. Supplementary plating or bolting should only be used if fixation and immobilisation cannot be obtained in any other way.

*Karlén* (1944) uses cancellous chips and block grafts for *arthrodesis* of the hip.

*King* (1948) uses block grafts and iliac chips for *spinal fusion* and reports satisfactory consolidation in 90 % of cases. This is confirmed by experiments performed by *Ghormley & Stuck*, and confirmed clinically by *Break & Basom* (1943).

*Earlier Experimental Works.*

The clinical results of cancellous grafts show a healing percentage of 90-95 %, as compared with 80-85 % for other forms of bone grafting. It has not been possible to confirm these clinical results experimentally, mainly because of our insufficient knowledge of the biology of bone growth and of the main factors influencing it. For this reason "pure" experiments are very difficult to plan.

The numerous investigations with different types of transplants—periosteal, endosteal and cancellous bone, marrow, extracts, os purum and bank bone—have shown that all have some osteogenetic effect. (Mayer & Wechner 1914, de Josselin de Jong & van der Kemp 1928, Orell & Engström 1943, Lexer 1924, Brooks 1917, Bachkirzev & Nemilov 1912, Policard & Leriche 1928, Levander 1938, Annersten 1940, Hellstadius 1943, Bertelsen 1944).

Various views have been put forward as to which type has the greatest osteogenetic effect. Especially regarding the relative values of cancellous and cortical bone are the authors divided.

There is no doubt about the osteogenetic effect of cancellous bone, though some investigators believe that this effect is less than in cortical bone (Hellstadius 1943 a. o.), while others believe that cancellous bone, especially in the form of chips, has the greater osteogenetic effect (Partsch 1922, Matti 1932, Mowlem 1943).

Marehand (1901) believed that after transplantation cancellous grafts died and were absorbed. He, however, used homotransplants from the femoral condyles of dead dogs and implanted them into the frontal bones of young dogs.

Partsch (1922) showed that iliac cancellous bone was still living three weeks after transplantations to the mandible.

Matti (1932) believed that cancellous bone had a better chance of survival, because the vessels grow more easily into cancellous transplants to join with the vessels of the transplant. Mowlem is of the same opinion. Matti also states that cancellous bone is more resistant to infection in the tissues than cortical bone.

The views of Partsch, Matti and Mowlem remained unopposed until Stuart Gordon, working with the bone cytologist Ham, published the results of a large-scale experimental work in dogs. They inserted small grafts which they removed after different intervals. They showed that the grafts were gradually absorbed and replaced by new bone tissue. Only a small part of the new bone appeared to be formed from the graft itself—perhaps from the marrow cells—while the greater part was formed by the recipient tissue which was stimulated to form bone by the presence of the cancellous graft.

These results agree with those of Bertelsen, who continued Levander's and Annersten's investigations into the induction of bone and cartilage

formation in muscles. He showed that extracts of the marrow of young bone induced cartilage and bone formation at the site of injection twice as often as extracts of periosteum, epiphysis, and cortical bone.

Abbott, Schottstaedt, Saunders, & Bost (1947) transplanted cancellous bone both with and without periosteum and also combined cortical and cancellous grafts (ribs) to the abdominal wall of dogs and rabbits. They, like Gordon and Ham, found that all mature elements died, while the endosteal cells with osteogenetic properties alone survived. Cancellous bone had the greatest osteogenetic activity.

Thus both clinical and experimental observations, which show the importance of the red bone marrow for new bone formation, are available. Clinical work has also shown that cancellous bone gives better results than cortical bone. Recent experimental work must also be regarded as supporting this view.

#### OWN MATERIAL

29 cases have been treated since 1947. All were given post-operative penicillin for three days or until their temperatures were normal. Infected cases were also given preoperative penicillin.

A. 9 cases of *chronic haematogenous osteomyelitis*. The most important details are shown in table 1, pag. 486.

Thus the majority of the cases were of very long standing. In the above table only chisellings are included among previous operations, not scraping of sinuses or simple sequestrectomies. Case No. 7 had had a resection of the knee-joint.

5 cases had sinuses. In 6 direct suture seemed justifiable after mobilisation of the skin. In 2 the skin was sutured after a counter incision and advancement of the flap. In one case, where primary direct suture was tried, a cross-leg-flap was necessary later. See Fig. 1.

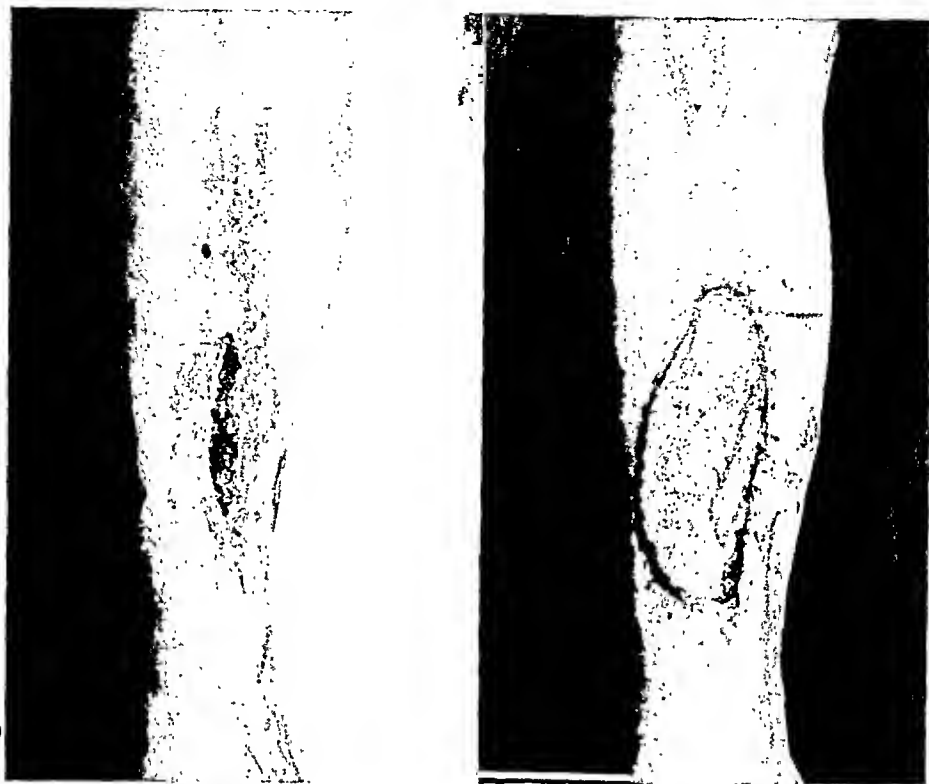
Thus the attitude to plastic skin surgery was conservative, and it is possible that our experience will lead us to be more radical in the future.

2 cases, Nos. 817/49 and 2035/47, have not been included in the material since they were only treated for residual discharge from unstable ulcerating scars, although the bone process was healed. Both healed after cross-leg-flap.

In all cases the bone focus was treated by radical chiselling,

TABLE 1  
*Chronic haematogenous osteomyelitis.*

	Nr.	Age	Sex	Site	Preoperative duration	Number of previous operations	Shus	Skin covering
1.	174/48	39 years	M	tibia	20 years	4	14 years	cross-leg-flap
2.	1500/48	37 "	M	tibia	22 "	3	÷	direct suture
3.	1702/48	33 "	M	femur	16 "	2	16 years	bridge flap
4.	401/49	17 "	M	femur	4 "	3	÷	direct suture
5.	623/49	31 "	F	humerus	15 "	3	15 years	direct suture
6.	629/49	16 "	M	tibia	5 "	1	5 "	bridge flap
7.	1158/49	62 "	M	tibia	48 "	3	÷	direct suture
8.	1362/49	71 "	F	tibia	2 "	0	÷	direct suture
9.	1517/49	12 "	M	femur	4 "	1	4 years	direct suture



*Fig. 1.*

and the cavities were saucerized and packed with cancellous chips from the crest and all of the ilium. Fig. 2 shows the radiograph of a case with an active focus before operation, shortly after grafting and after healing. Preoperatively there had been a discharging sinus.

The follow-up period is still very short, since up till 1948 the routine method in this department was packing with penicillin and sulfathiazole. 3 cases had been observed for less than 6 months post-operatively, 2 for between 6 and 7 months, and only 4 for more than 1 year. No case has a sinus or any residual process on the radiograph. In 1 case (No. 8) the leg was amputated, 5 months after the osteomyelitis operation, for tuberculosis of the ankle-joint. This case also had a spina ventosa but neither the anatomical findings nor the microscopic appearance of the specimen obtained at operation showed any evidence of tuberculosis in the tibial focus, nor



a



b



c

*Fig. 2.*

any connection between the completely healed operation area and the tuberculous focus in the ankle.

In one case discharge persisted for 6 months, and then ceased after a small sequestrum of the size and shape of a chip had been discharged. In another case a sinus which had not been excised continued to discharge. It was on the medial side of the thigh, while the operation had been performed on the lateral side. This sinus has recently been excised. There was no clinical or radiographic evidence of activity in the bone.

We are inclined to attribute these complications to insufficient radical treatment of the skin, rather than to the bone grafting method.

*B. 3 cases of infected pseudarthrosis with fracture-osteomyelitis.* Table 2, pag. 490.

In cases 10 and 11 pseudarthroses had been treated previously by cortical bone grafts and had also had several sequestrectomies. Case 12, which was rather a case of delayed union due to the osteomyelitis, had been treated earlier with an intramedullary Kirschner wire.

In case 12 cancellous chips were used alone. In case 11 they were combined with a block graft from the iliac crest, and in case 10 with a tibial graft.

All three cases have healed without sinus formation. They have been followed for 1 to 2½ years. Case 11 had a discharge from several small fistulae until 3 small sequestra (united cancellous chips) were discharged. The sinuses then closed. In this case the covering skin was thin, tight and chronically eczematous.

*C. 3 cases of uninfected pseudarthrosis.* Table 3, pag. 490.

In case 13 a sliding graft and ilium chips were used. In case 14 both a whole graft and chips from the ilium and a vitallium screw. In case 15 a local cortical graft, iliac chips and two vitallium screws.

Cases 13 and 14 are clinically and radiologically consolidated, but case 15 is still not united 9 months after operation.



TABLE 2

	No.	Age	Sex	Site	Preoperative duration	Number of previous operations	Sinus	Skin covering
10.	1119/47	37 years	M	humerus	3 years	3	3 years	direct suture
11.	1530/48	44 "	M	tibia	24 "	2	1 1/2 "	direct suture
12.	1604/48	16 "	M	tibia	7 months	1	7 months	direct suture

TABLE 3

	No.	Age	Sex	Site	Preoperative duration	Number of previous operations	Skin covering
13.	739/47	36 years	M	II metacarpal	2 1/2 years	0	direct suture
14.	1216/47	23 "	M	tibia	6 months	0	direct suture
15.	2373/48	46 "	M	femur	1 1/2 years	6	direct suture



Fig. 3.

This case has previously had 6 chisellings for osteomyelitis from 17 to 3 years before admission. The fracture was 18 months old. At follow-up he can bear weight on the leg. He works as manager of a factory and uses a stick for walking, but he feels unsteadiness and there is 20 degrees' angulation, open posteriorly, at the fracture line. There was already 10 degrees' preoperative angulation. Radiographically—using special views—there is bony contact posteriorly for a small finger's breadth. The rest of the fracture line is not filled in, though there is no sclerosis of the edges. Thus there is still a possibility of consolidation, but we now realize that the cortical, stabilizing graft should not have been taken from pathological, sclerotic bone.

In these 3 cases there was no difficulty with the skin covering. It is well known that the skin may be important for consolidation in cases of delayed union and for a satisfactory result in pseudarthrosis operations. This is illustrated by another case from this department.

A man (nr. 1449/47), age 42 years, has had a compound infected fracture of the tibia for 2½ years. A sequestrectomy had been performed in 1945, chiselling and packing with local chips in 1946, chiselling and packing with penicillin and sulfathiazole in April 1947. In July 1947 there was still a pseudarthrosis with a sinus, and the patient favoured amputation in order to shorten his illness. The sinus and poor skin

TABLE 4

	No.	Age	Sex	Site	Diagnosis	Operation
16.	436/48	52 years	M	C4—T1	Spondylitis deformans with root compression	H-shaped pieces of ilium + ilium chips
17.	668/48	30 "	F	L4—S1	Tuberculosis of the 5th lumbar vertebra	H-shaped pieces of ilium + ilium chips
18.	1053/49	53 "	F	Hip	Necrosis of the femoral head after fracture	Nailing arthrodesis ilium graft, and juxta- and intra-articular chips
19.	1415/49	38 "	M	right thumb	Traumatic amputation of the right thumb	Skin tube from the abdomen, iliac graft and tendon suture. 3 months later arthrodesis between transplant and metacarpal graft using iliac chips and a



Fig. 4.

were excised, the bone was drilled and a dermatome graft 4 by 8 cm was applied. Five weeks later the skin was solidly healed. There was no sinus, and the fracture was clinically firm.

*D. Arthrodesis, 4 cases.*

All cases showed bony union. The result in case 19 is shown in fig. 3.

The functional results are good except in case no. 16, in which the patient has pain below the level of fusion as well as in the lower thoracic spine, where the spondylosis is progressing.

It is doubtful whether the operation was indicated in this case, but the patient's condition was intolerable because of pain in the neck and throat. A rhizotomy of the 2nd and 3rd cervical nerves had previously been done by the neurosurgeons for the same reason.

*E. Cases of correction of facial skeletal defects.* Table 5, pag. 494.

Follow-up examinations have found the patients satisfied

TABLE 5  
(Cases in which grafts or chips were used alone, i.e. nose plastics are not included)

No.	Age	Sex	Region	Diagnosis	Operation
20.	26 years	F	Forehead	Defect after resection of frontal osteoma	Ilium graft and chips
21.	41 "	F	Infraorbital	Sequelae of fracture of the zygoma	Ilium graft and chips
22.	37 "	F	Forehead	Sequelae of frontal sinusitis	Ilium graft and chips
23.	16 "	F	Forehead, maxilla and mandible	Facial hemiatrophy	Ilium graft, chips + corium, fat & fascia graft
24.	29 "	M	Forehead	Sequelae of frontal sinusitis	Ilium graft and chips
25.	47 "	M	Infraorbital	Sequelae of orbital lesion	Chips
26.	28 "	M	Nose & forehead	Congenital deformity	Ilium graft and chips

TABLE 6

	No.	Age	Sex	Region	Diagnosis	Operation
27.	234/49	27 years	F	Phalanx	Enchondroma	Enucleation, ilium chips
28.	1511/49	24 "	M	Femur	Fibrous dysplasia	Enucleation, chips
29.	1321/49	33 "	F	Ischium	Chondromyxosarcoma	Excision of the ischium and part of the pubis and aceta- bulum; ilium graft + chips

with the results. "Re-touching" operations have so far been necessary in two cases; thus a small corner of the transplant was absorbed in case 20. It was re-grafted. Case 22 was rather over-corrected because of this experience, but reabsorption did not occur and secondary chiselling of the excessive bone was necessary. Case 23 see fig. 4.

F. *Bone defects after operations for tumours and cysts, 3 cases.* Table 6, pag. 495.

In case 27 there is clinical and radiographic union. The other two cases are too recent.

To summarize, cancellous bone chips from the ilium have been used in 29 cases, sometimes combined with whole grafts, which were mainly also taken from the ilium. Vitallium screws were also used in two cases. Nine cases have been observed for less than six months. Of the remaining twenty cases there is clinical and radiographic union in all but one.

## SUMMARY

Clinical and experimental work on bone grafting is reviewed, and our own experience is described.

29 cases are reported. Cancellous ilium chips were used in all; in some they were combined with block grafts, mainly taken from the ilium. Vitallium screws were also used in two cases. All cases received postoperative penicillin treatment. 9 cases have been observed for less than 6 months. Of the remaining 20, 19 show clinical and radiographic union.

9 cases of long-standing haematogenous chronic osteomyelitis were treated. The bone focus was widened and saucerized and packed with cancellous chips. Solid skin covering must be provided in these cases. The observation period is over 1 year in only 4 cases. 2 had persistent discharge, both without radiographic evidence of activity in the bone. From one a sequestrum resembling a chip was removed, in another the sinus was excised. In both, the discharge stopped. We attribute these complications to poor skin covering.

3 cases of infected pseudarthroses were treated in the same way. All of them healed, 1, with poor skin covering, only after the discharge of 3 small sequestra. 3 cases with uninfected pseudarthroses were treated by cancellous chips combined with a local cortical graft, an ilium graft, and an ilium graft + vitallium screws, respectively. 2 are clinically and radiographically consolidated, 1 shows only partial union 9 months after operation.

In 4 cases the method was used for arthrodesis, all show bony ankylosis.

In 7 cases cancellous chips were used for defects of the facial bones with satisfactory results.

In 3 cases cancellous grafts were used for bone defects following excisions of tumours and cysts. 1 is united; in the other 2 the observation time is too short.

## RESUME

Le travail clinique et expérimental de la transplantation osseuse est passée en revue et les propres expériences de l'auteur décrites.

29 cas sont rapportés. Des fragments spongieux d'os iliaque ont été utilisés dans tous les cas; de plus, des greffes osseuses, prélevées principalement de l'os iliaque ont été utilisées dans certains cas et des vis de vitallium dans deux. On a donné de la péniciline à tous les malades avant et après l'opération. 9 cas ont été observés pendant une période inférieure à six mois. Sur les 20 autres, on a constaté chez 19 une consolidation clinique et radiographique.

9 cas d'ostéomyélite hématogène chronique anciens ont été traités; on a pratiqué un curettage étendu du foyer intra-osseux que l'on a ensuite rempli de fragments d'os spongieux. Il faut veiller à ce qu'il y ait dans ces cas une solide couche *dermique*. La période d'observation s'est étendue sur plus d'un an dans 4 cas seulement. Dans 2 cas il y a eu suppuration persistante bien qu'il ne semblait pas y avoir d'infection osseuse active. Un cas s'est guéri après extraction d'un séquestre



et l'autre après excision du sinus. Nous attribuons ces complications à une couverture imparfaite dermique.

3 cas de pseudarthrose avec infection ont été traités de la même manière ; tous ont été guéris, l'un après extraction de trois petits séquestres.

3 cas de pseudarthrose sans infection ont été traités par fragments d'os spongieux combinés respectivement avec une greffe corticale locale, une greffe d'os iliaque et une greffe d'os iliaque + vis de vitallium. 2 montrent une consolidation clinique et radiographique ; chez un autre la jonction n'est que partielle neuf mois après l'opération.

Dans 4 cas la méthode a été appliquée contre l'arthrodèse : il y avait chez tous de l'ankylose osseuse.

Dans 7 cas on utilisa des fragments d'os spongieux pour réparer des os de la face défectueux et l'on obtint des résultats satisfaisants.

Dans 3 cas des greffes d'os spongieux ont été utilisées pour réparer des os à la suite d'ablation de tumeurs ou de kystes. Il y a eu jonction dans un cas. Dans les deux autres la période d'observation est trop courte.

#### ZUSAMMENFASSUNG

Das klinische und experimentelle Werk über Knochen-  
transplantation wird besprochen und die eigenen Erfahrungen  
der Verfasser werden beschrieben.

29 Fälle werden mitgeteilt. Spongiöses Gewebe vom Ileum  
wurde in allen Fällen verwendet. Ausserdem wurden in eini-  
gen Fällen solide Spangen, meist vom Ileum entnommen, und  
in zwei Fällen Vitalliumschrauben gebraucht. Alle Fälle er-  
hielten prä- und postoperativ Penicillin. In 9 Fällen war die  
Beobachtungsdauer kürzer als 6 Monate. Von den 20, zeigen  
19 klinische und röntgenologische knöcherne Heilung.

9 Fälle von lang bestehender hämatogener Osteomyelitis  
wurden behandelt. Der Knochenherd wurde breit ausge-  
seilt und mit spongiösem Knochengewebe gefüllt. Für eine  
Deckung mit solider Haut muss in diesen Fällen gesorgt wer-

den. Die Beobachtungsperiode ist nur in 4 Fällen über ein Jahr. 2 Fälle zeigten persistierende Sekretion, obwohl keine Anzeichen für eine aktive Infektion im Knochen vorhanden war. Ein Fall heilte nach Entfernung eines Sequesters, der wie einer der transplantierten Knochenspähne aussah. Der andre Fall heilte nach Excision der Fistel. Man sucht die Ursache dieser Komplikationen in ungenügender Hautdeckung.

3 Fälle von infizierter Pseudarthrose wurden in derselben Weise behandelt. Alle heilten, einer erst, nachdem drei kleine Sequester ausgestossen worden waren.

3 Fälle von nicht infizierten Pseudarthrosen wurden mit spongiösen Knochenspähnen, kombiniert mit lokalem Kortikalisspahn respektive mit Ileumspahn und Ileumspahn mit Vitalliumschraube, behandelt. Zwei sind klinisch und röntgenologisch konsolidiert. Einer zeigt nur teilweise Vereinigung 9 Monate nach der Operation.

In 4 Fällen wurde die Methode zur Arthrodesen benutzt. Alle zeigen knöcherne Ankylose.

In 7 Fällen wurden spongiöse Knochenspähnen benutzt um Defekte der Gesichtsknochen zu reparieren, mit zufriedenstellendem Resultat.

In 3 Fällen wurden spongiöse Knochenspähne verwendet bei Defekten die der Excision von Tumoren und Zysten folgten. Ein Fall zeigt Heilung. In den anderen beiden Fällen ist die Beobachtungszeit zu kurz.

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## OPERATIVE TREATMENT OF FRACTURES OF THE HEAD AND NECK OF THE RADIUS

BY

NILS CARSTAM

Fractures of the upper end of the radius are more common than has been previously thought, and their treatment has frequently given unsatisfactory results, with persistent trouble in the form of pain and restricted movement, which sometimes cause considerable disability. The abundant literature published during the last 20 years shows general agreement as to certain principles of treatment, especially on the question of conservative versus operative treatment, but there are still varying opinions as regards the selection of the type of operation for the different fractures. Papers dealing with this rarely quote more than a few cases as examples of each method, and, with a few exceptions, it has not been possible to make any real comparison between the different methods of operation on a reasonably large number of cases. As I have had the opportunity of examining a rather large number of fractures of the head and neck of the radius treated by operation, I feel justified in publishing the results.

### *Types of Fractures:*

The head of the radius is a rather thin disc, 3-5 mm. thick, and is supported by the cylindrical neck, 1.5-2.5 cm. long, which ends distally at the tuberosity of the radius. A fracture may involve only the head, but it usually extends to the neck as well. Fractures of the neck of the radius are most common in children and young people, and the two main types are

the oblique and the so-called greenstick fractures. Many different groupings of the types of fractures have been put forward, but the majority can fit into the scheme suggested by Speed.

I. Incomplete fractures, fissures, cracks.

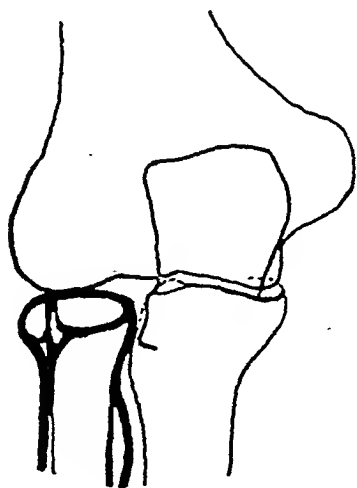
II. Complete fractures

(a) Partial, marginal fractures, with displacement of one or more fragments.

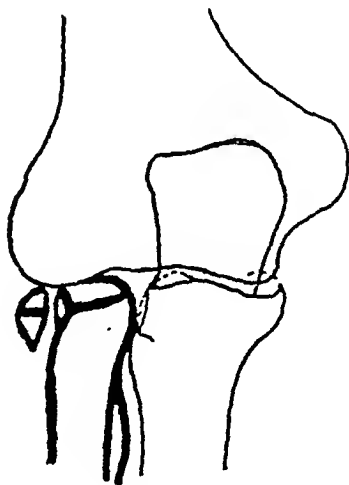
(b) Total fractures, including comminution or crushing of the head.

(c) Fractures of the neck.

I have followed this grouping, with only slight modifications, necessitated by, among other things, the restriction of the material available to fractures treated by operation. Fractures without any displacement have, of course, not been treated by operation, and are, therefore, not dealt with here. The grouping has been based on the descriptions of the fractures in the operation reports and on examination of the radiographs. The cases have been divided into the following groups:



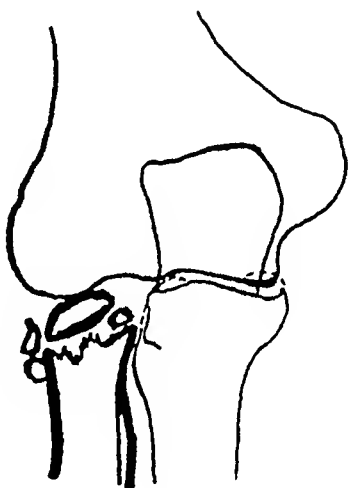
*Type I.*



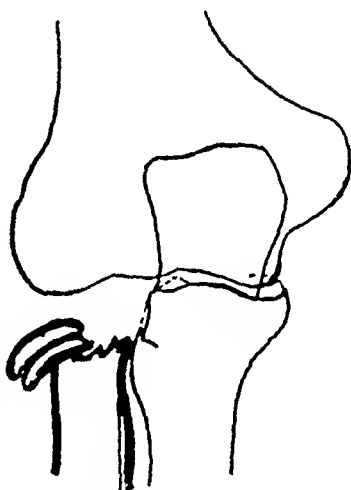
*Type II.*

*Type I. Marginal fractures with depression or very slight displacement.* Material available in this group is very scarce, as these fractures are usually treated conservatively.

*Type II. Marginal fractures with greater displacement.* As in the preceding group, the fracture-line often extends vertically into the neck. There is usually only one displaced fragment, but this may sometimes be splintered into smaller fragments. The displaced part may lie at an angle, or it may be rotated in relation to the rest of the head, or it may be completely displaced, lying free in the joint cavity, or even forced outside it. The fragment usually carries less than one third of the articular surface, though an even bigger piece can be displaced.



*Type III.*



*Type IV.*

*Type III. Comminuted fractures.* In this group, the head is splintered into a number of fragments, which may be considerably displaced. The articular surface often shows stellate fissures and is separated from the neck, but in some cases part of the articular surface is intact.

*Type IV. Fractures of the neck.* Both marginal and comminuted fractures often involve the neck, but they have not been included in this group, which deals with fractures involving only the neck, where there is either an oblique or an irregular transverse fracture, and the articular surface is intact. A considerable proportion of these fractures is made up of the so-called greenstick fractures in children. The fractures may

be intra- or extra-capsular, or both. From a therapeutic point of view, *Hitzrot* included only the extra-capsular fractures in this group, but sufficient reason for this limitation is lacking. These fractures are sometimes combined with partial displacements of the epiphysis. Isolated displacement of the epiphysis is very rare, and has not been observed in this material.

#### MATERIAL

During the 20-year period—1928-1947—95 cases of fresh fractures of the head and neck of the radius have been treated surgically at the Orthopaedic and Surgical Clinics of Lund and Malmö. Re-examination has been possible in 81 of these cases (85.3 per cent.). Of the remaining 14 patients, 4 have died and 10 have either not been traced or live too far away.

By "fresh fractures" is understood cases which have been operated upon within the first month after injury. As a rule, the operation has been performed within an average of 6 days of the injury. The period of observation varies from 2 to 20 years, with an average of 8 years. The age groups of the 81 cases in which re-examination was possible is given in the following table:

*Age Groups.*

< 10	10-20	20-30	30-40	40-50	50-60	60-70	> 70
1	11	14	12	17	20	4	2

*Age-Grouping of the Types of Fractures.*

	No.	Percentage	Average Age
Marginal fracture with slight displacement .....	5	6	37 years
Marginal fractures with marked displacement .....	25	31	46 „
Comminuted fractures .....	34	42	42 „
Fractures of the neck .....	17	21	23 „
Total .....	81	100	



## SEX INCIDENCE

Of the 81 patients, 62 (77 per cent.) are females and 19 (23 per cent.) males. Of the total 95 fractures the proportions were 75 per cent. and 25 per cent. respectively.

## FRACTURES COMBINED WITH OTHER LESIONS

A fracture of the head or neck of the radius is as a rule not an isolated injury, but occurs simultaneously with injuries to the bone, capsule and soft tissue in and around the elbow. In 18 cases a dislocation was found when the patients were admitted to hospital, but it can be reasonably supposed that dislocation occurred in a greater number of the cases but had been spontaneously reduced, because, in many instances, besides a fracture of the head of the radius, there was an isolated displacement of the coronoid process; this must have been produced by a momentary luxation or sub-luxation, as demonstrated by *Odelberg-Johnson* on corpses. *Hein* concluded from the material at his disposal that "the dislocations of the elbow were of sufficient frequency to be considered a likely complication of all fractures of the head of the radius".

A study of the radiographs taken at the follow-up examinations shows, in nearly all cases, changes which suggest the avulsion of small bone fragments, especially at the capsular attachments, and calcifications of the capsule. If the head of the radius has been damaged to such an extent that it requires surgical treatment, the case is not likely to be uncomplicated. I have therefore included in the same group all the cases described in the notes and reports on operations as being uncomplicated, and all the cases which showed dislocation fractures of the coronoid process and other minor injuries. I have excluded cases of fracture of the head of the radius where this fracture was only of minor importance in comparison with the other bone injuries as, for example comminuted fractures of the upper end of the ulna. Similarly, I have excluded other bone injuries caused by violent force and which have required special therapy, which might considerably influence the final

results. For this reason, 7 of the 81 cases have not been included in the analysis of the final results, and only 74 therefore remain. As the intention is to compare the final results of different fracture types and methods of operation, the grouping mentioned above has little effect on the results, since the diagnosed minor complications occur to about the same extent in the different groups.

### TREATMENT

The surgical methods used in this material and discussed here, are:

- 1) Open reduction.
- 2) Partial excision, and
- 3) Total excision of the head of the radius.

The choice of operative method is partly dependent on the type of fracture; thus one can hardly reduce a comminuted fracture and sometimes, with severe crushing of the head, mere partial excision of fragments is not sufficient. In other cases of comminuted fractures, however, one can choose between removing displaced fragments and leaving that part of the articular surface which remains connected to the neck; or one can make a total excision of the head. The same applies to marginal fractures with displacement, but in these cases, open reduction is sometimes possible. Finally, for fractures of the neck it is possible to perform either an open reduction or a total excision of the head.

### OPEN REDUCTION

This is generally considered to be the best treatment for fractures of the neck, especially in young patients where a closed reduction has been unsuccessful (*Pfab, Key, Madlener and Wienert, Hertel Oppolzer, Murray, Roosvall*). In this material, open reduction was performed in 10 cases, for both fractures of the neck and marginal fractures with depression or slight displacement. Neither fixation of the fragment or the head, as recommended by *Sprengell and others*, nor replace-

ment of a splintered head by a vitallium cup, as described by *Speed*, has been attempted.

*Partial excision* is recommended as the best method, whenever possible, by *Lassen, Buxton, Hertel, Siebner*, whereas others stipulate that it is inadvisable where it involves the removal of more than one-third of the head (*Wilson, Jones, Eliason* and *North*). In the present series fragments were removed in 33 cases, and in approximately 50 per cent. less than two-thirds of the joint surface was left.

*Excision of The head:* Opinion is strongly divided as regards the results of this operation. *Hitzrot, Speed, Pfab, Bohrer, Wilson, Jones, Murray, Watson-Jones, Meekison, Jacobs* and *Kernodle* have obtained satisfactory results and prefer this method, even where removal of fragments would be possible. Other authors report less successful results and warn against the method, especially in regard to the secondary complications of cubitus valgus and wrist complications (*Thomsen, Lewis* and *Thibodean, Cubbins—Callahan—Scuderi, King, Lang*). To prevent excessive new bone formation from the neck, and the consequent risk of synostosis and restricted movement after total excision of the head, different techniques have been suggested, e.g. to cover the end of the neck with fascia, with a fat transplant, or with a capsular flap. In order to obtain as free movement as possible and to reduce the risk of excessive callus formation, *Hitzrot, Speed* and *Sever* recommend total excision to include the neck down to the tuberosity, whereas others, e.g. *Thomsen*, advise removal of as little as possible of the neck, to avoid the risk of wrist complications. *Bergk*, on the other hand, attaches no importance to the size of the part removed. In this material, where excision of the head was performed in 31 cases, no special effort was made to cover the end of the neck, although in a few cases the olecranon bursa used as a covering, and in some the marrow cavity of the neck was scraped out. In order to be able to estimate the late results in these cases, I have tried to differentiate between excision of the head alone, and a more radical removal of the head and neck. I have

based this differentiation on the reports of the operations and examination of the radiographs.

### OPERATIVE TECHNIQUE

In this material lateral longitudinal incisions, often of Kocher's type, were mostly used. The annular ligament was usually divided, and either left free or sutured. Radiographs taken after operation sometimes showed that small fragments had been left behind, both in cases where fragments had been removed and in those, where a resection of the capitulum had performed.

Plaster slabs or plaster casts were applied and left for 2-3 weeks, after which physio-therapy was instituted for varying periods of time.

### RE-EXAMINATION

I have personally examined the re-examined patients. All were asked about pain and their ability to work. Restricted movement of the elbow and wrist, muscular atrophy, deformities and crepitations were recorded, the strength of the hand was measured, and radiographs were taken of both elbows and both wrists.

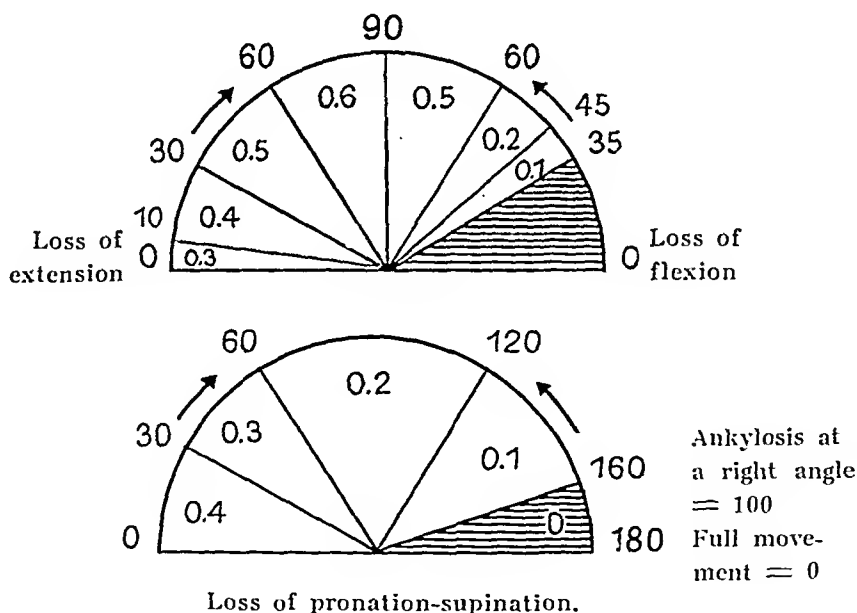
### CRITERIA FOR ASSESSMENT

The patients have been classified in 3 groups, according to their symptoms:

- A. Symptom-free
- B. With mild symptoms
- C. With more severe symptoms and disability.

The complaints do not correspond to the objective changes, such as restricted movements, deformity and changes demonstrable on the radiographs. The restriction of the different movements of the elbow varied considerably, and it is extremely difficult to compare the result in one patient who has considerably reduced extension, with that in another who has severely reduced pronation and supination, but full ex-

tension. In order to form a basis for comparison of the different reductions of movement, I have tried to assess them according to the system compiled by *Ferguson* and *Howorth*, and further developed by *Gade*, in regard to the hip joint. Thus, the severity of the restriction is assessed according to not only the different planes, but also the position in these planes. The range of movement is expressed in degrees in different sectors and, in order to obtain conformity, these degrees are multiplied by different coefficients. This evaluation is, however, quite subjective and the scheme only obtains for the cases under discussion, and not for the elbow in general, because, amongst other things, I have not considered a loss of flexion greater than  $90^\circ$ , as no such case was encountered in this material.



The limitations of movement have been assessed by this system, and the cases have accordingly been divided into the following groups:

0	—	5	= a
5.5	—	10	= b
10.5	—	20	= c
20.5	—	100	= d

This grouping has then been combined with the grouping according to the subjective complaints, giving the following 4 groups:

perfect	good		fair		poor	
Aa	Ab	Ac	Ad		Bd	Cb
	Ba	Bb	Bc	Bd	Cc	Cd

### RESULT

The results of the treatment of fractures of the head of the radius agree with *S. Jones'* statement that: "The prognosis is good for recovery of a useful elbow, rarely is it a normal elbow".

Based on the assessments already given, the following results are obtained in relation to the types fractures:

	Marginal Fracture		Comminuted Fracture		Fracture of the Neck		Total	
	Cases	%	Cases	%	Cases	%	Cases	%
Subjective:								
A. Symptom-free .....	14	54	7	21	3	20	24	32
B. Mild symptoms .....	10	38	21	64	11	73	42	57
C. More severe symptoms .....	2	8	5	15	1	7	8	11
Subjective + objective:								
Perfect .....	9	35	2	6	3	20	14	19
Good .....	5	19	16	49	4	27	25	34
Fair .....	8	31	9	27	3	20	20	27
Poor .....	4	15	6	18	5	33	15	20
Total .....	26		33		15		74	

As may be expected, this shows that marginal fractures, which represent the least severe type, form the majority of the fractures in the "Perfect" group. The different types in the group "Poor" are fairly evenly represented, with a slight preponderance of fractures of the neck, but here the use of what is now considered an unsatisfactory method of operation may have played an important role, as is shown in the follow-

ing table. This table also shows that the severity of the fracture is important, because from amongst the marginal fractures a group with only slight displacement, which shows considerably better results, can be regreated.

Marginal fractures			
	With slight displacement	With marked displacement	
		fragment $< \frac{1}{3}$	fragment $> \frac{1}{3}$
Perfect .....	4	3	2
Good .....	1	2	2
Fair .....		5	3
Poor .....		3	1

The marginal fractures with serious displacement have been subdivided into two groups according to the size of the fragment. It is often said that two-thirds of the articular surface should be intact for it to be advisable to perform partial excision, but the results in the present material do not support this theory.

#### RESULTS OF DIFFERENT METHODS OF OPERATION

In the following table the cases are grouped in accordance with the method of operation and irrespective of the type of fracture:

##### *The Results in Relation to the Type of Operation. All Cases.*

	Partial excision		Total excision		Open reduction	
	No.	%	No.	%	No.	%
Perfect .....	7	21	1	3	6	60
Good .....	10	30	13	42	2	20
Fair .....	10	30	9	29	1	10
Poor .....	6	18	8	26	1	10
Total .....	33		31		10	

As already mentioned, these figures are not quite com-

parable, on account of the influence the type of fracture will have on the results, and the methods of operation should, therefore, be compared within the fracture groups. In this material, total excision of the head has not been used for marginal fractures, and the only group where the results of partial and total excision can be compared are the comminuted fractures, but even here a certain selection was made, as partial excision was only used if some part of the head was uninjured. On the other hand, it should be mentioned that in this group a bigger portion of the head and its joint surface was removed than is usual in cases of partial excision.

*The Results of Operations for Comminuted Fractures.*

	Partial Excision	Total Excision
Perfect .....	1	1
Good .....	6	10
Fair .....	2	7
Poor .....	2	4

If the relatively similar groups, marginal fractures with considerable displacements are added to the comminuted fractures, the following figures are obtained:

*The Results for Marginal Fractures with Considerable Displacement and for Comminuted Fractures Combined.*

	Partial Excision	Total Excision
Perfect .....	6	1
Good .....	10	10
Fair .....	10	7
Poor .....	6	4

This table does not show that any particular method of operation is superior, in contradiction to *Murray* who states a preference for total excision over partial excision.

The results of partial excision and open reduction can be compared for the marginal fractures, where open reduction was performed on 4 cases with only slight displacement.



*The Results of Marginal Fractures Treated by Partial Excision and by Open Reduction.*

	Partial Excision	Open Reduction
Perfect .....	6	3
Good .....	4	1
Fair .....	8	
Poor .....	4	

The cases where open reduction was used belong to a group not usually treated surgically, but notably good results were obtained in this group.

For fractures of the neck total excision was performed in 9 cases and open reduction in 6:

*The Results of Operations for Fractures of the Neck of the Radius.*

	Total Excision	Open Reduction
Perfect .....	—	3
Good .....	3	1
Fair .....	2	1
Poor .....	4	1

The results for fractures of the neck which are generally regarded as most satisfactory after open reduction, are shown clearly in the above table.

If the comminuted fractures are grouped according to the extent of the total excision, the following difference in the results is obtained:

*Total Excision.*

	Excision of head	Excision of head + neck
Perfect .....	—	1
Good .....	5	5
Fair .....	6	1
Poor .....	3	1

The above figures seem to advocate removal of the head sufficiently far down in the neck. Although this increases the

risk of cubitus valgus and upward displacement of the radius, with a consequent faulty position of the wrist, the complaints are not sufficient to outweigh the advantages obtained.

It might be of interest to compare the different methods of operation in relation to the nature of the resulting restriction of movement. *Bohrer* states that, following surgical treatment of a fracture of the head, extension-flexion was usually only slightly restricted, but there was considerable loss of rotation, or even synostosis between the radius and ulna, in 50 per cent. of his cases. *Baumann*, on the other hand, reports that rotation is rarely reduced after removal of a fragment, though limitation of extension and flexion is very frequent, whereas *Pfab* disagrees; *Speed* considers that total excision of the head is necessary to avoid limitations of rotation.

*Average Figures for Limitations of Movement after Different Types of Operation.*

	No. of cases	Loss of Extension	No. of cases with full extn.	Loss of flexion	No. of cases with full flexion	Pronation-Supination		No. of cases with full pronation-supination
						Loss compared with sound side	Range of Movement	
Removal of fragments	33	15°	14	6°	15	42°	114°	3
Total excision	31	17°	10	7°	11	41°	110°	5
Open reduction	10	2°	9	6°	5	31°	125°	4
Total	74		33		31			12

If the same calculation is made for only one type of fracture, the following figures are obtained:

*Marginal Fractures.*

	No. of cases	Loss of Extension	Loss of Flexion	Pronation-supination	
				Loss compared with sound side	Range of Movement
Removal of fragments	22	16°	6°	44°	112°
Open reduction .....	4	—	4°	—	158°
Total .....	26				

*Comminuted Fractures.*

	No. of cases	Loss of Extension	Loss of Flexion	Pronation-supination	
				Loss compared with sound side	Range of Movement
Removal of fragments	11	12°	8°	36°	117°
Total excision .....	22	16°	7°	38°	113°
Total .....	33				

*Fractures of the Neck.*

	No. of cases	Loss of Extension	Loss of Flexion	Pronation-supination	
				Loss compared with sound side	Range of Movement
Total excision .....	9	18°	9°	48°	101°
Open reduction .....	6	3°	8°	52°	102°
Total .....	15				

These figures confirm what has been said before about the advisability of open reduction for fractures of the neck, and whenever possible, perhaps, also for marginal fractures, but they do not show any definite difference between the results of removal of fragments and of total excision, and they do not tell us anything about the different functions of the joint.

*Wrist trouble* has been complained of by 5 out of the 74 patients, following surgical treatment of fractures of the head; total excision had been performed in 4 of them. A more serious loss of power in the affected hand was found in 25 of the 69 cases<sup>1</sup>.

There was an increase in the carrying angle on the injured side compared with the normal side in 31 of 71 cases; in 20 total excision and in 11 removal of the fragment had been performed. In addition, radiographs of the wrists were exam-

<sup>1</sup> Power was measured with a hand-dynamometer. The power was regarded as considerably reduced when it was the same or less than on the left side in cases of injury to the right side in right-handed patients, and vice versa.

ined and the proximal displacement of the radius on the injured side was measured and compared with the uninjured side. Proximal displacement was observed in 27 out of 35 cases of total excision—it varied between 1 and 7 mm. with an average of 2.5 mm; whereas it was observed in only 4 out of 33 cases with partial excision and open reduction—it ranged from 1-3 mm.

	Total Excision			Partial Excision	Open Reduction
	Radical excision	Conservative excision	Total		
Increase in carrying angle:					
average .....	8.1°	5.5°	6.6°	2.5°	—
Proximal displacement of end of radius .....	2.3	2.2	2.3	0.3	0.2
	mm.	mm.	mm.	mm.	mm.

A great number of the cases treated by total excision showed a moderate cubitus valgus, and in nearly all there was also a proximal displacement of the radius, averaging about 2 mm., with a corresponding radial displacement of the hand and prominence of the distal end of the ulna. In spite of these serious anatomical and radiographic changes, symptoms attributable to them were reported in a few cases only. Despite the rather long period of observation, it is still possible that patients with these changes, who at present are symptom-free, may develop complaints in the future. Among the patients who now have complaints, 3 are cases of fractures of the neck in young persons, where the injury took place 7-10 years ago, and 2 where the injury occurred 12-16 years ago.

### *Radiological Changes:*

With a few exceptions, radiographs taken at the time of injury have been available. By comparing these with radiographs taken at re-examination, it has been found, as mentioned previously, that the injury recorded as fracture of the neck of the radius is by no means limited to simple fracture;

in nearly all cases the radiographs taken at re-examination showed involvement of the capsule and surrounding tissue, such as small tears of the capsule attachments, calcification of the capsule and changes of a myositis ossificans-like nature. In a rather large number of cases there were calcifications and bone-formation on the small remaining fragments, while in one or two cases even large fragments had been left.

✓ Widespread calcification of the annular ligament was found in 5 cases and in others there were minor calcifications at the attachments. These do not, however, seem to cause any significant limitation of the movements. Fig. 1 shows calcification of the annular ligament in a case where the fragment, which was only slightly displaced, was reduced.

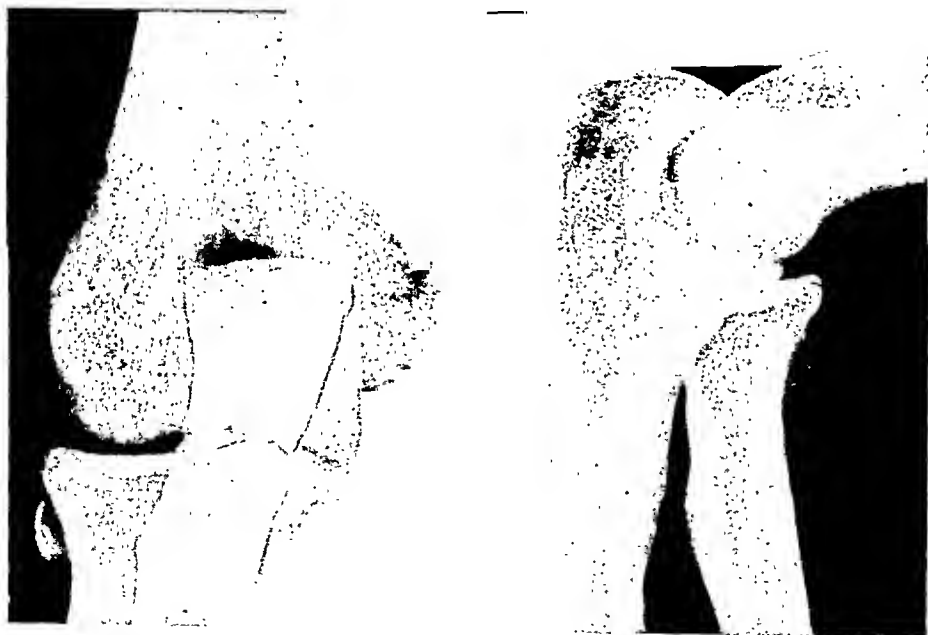


Fig. 1.

J.L.M. aged 34 years. Calcification of the annular ligament.

After removal of fragments, the remaining part of the head is rounded off and replaced, as a rule, by a somewhat clumsy, though quite normally shaped, head.

✓ After total excision certain changes are seen in the neck.

area, and their nature has been discussed. Re-establishment of contact between the head of the humerus and the remainder of the radius is generally found. This seems to be brought about partly by a displacement of the radius, which can be registered by measuring the position of the wrist, but the few millimetres which this involves are hardly sufficient by themselves, and it is supposed that a reconstruction of bone takes place, probably by organisation of the haematoma and the ingrowth of osteoblasts from the periosteum and medullary cavity (*Sutro*). That this new bone formation does in fact take place was also confirmed by examining this material, and a typical picture showing a bone formation pointed in a volar-radial direction, as well as a resorption of the neck area in a dorso-ulnar direction, were observed in 11 out of 31 cases of total excision. The real cause of these developments cannot be determined, but it is possible that static conditions play an important part. Fig. 2 shows a typical radius stump immediately after surgical treatment and at re-examination 3 years later. Judging by the distance from and relation to the tuberosity of the radius, this Fig. shows that resorption as well as new bone formation does take place.



Fig. 2.

S.S. aged 32 years. a. stump of radius after total excision  
b. appearance 3 years later.

The excessive new bone formation which *Sutro* describes, and for which he suggests remedies, has not been observed in this material.

In cases of total excision in children and young persons a reshaping of the stump into a more anatomically normal "new head", as has been described by *Sutro* and *Bergk*, can be seen. Fig. 3 shows a fracture in a 10-years' old girl, where the head of the radius was removed and the result compared with the uninjured side 10 years later.

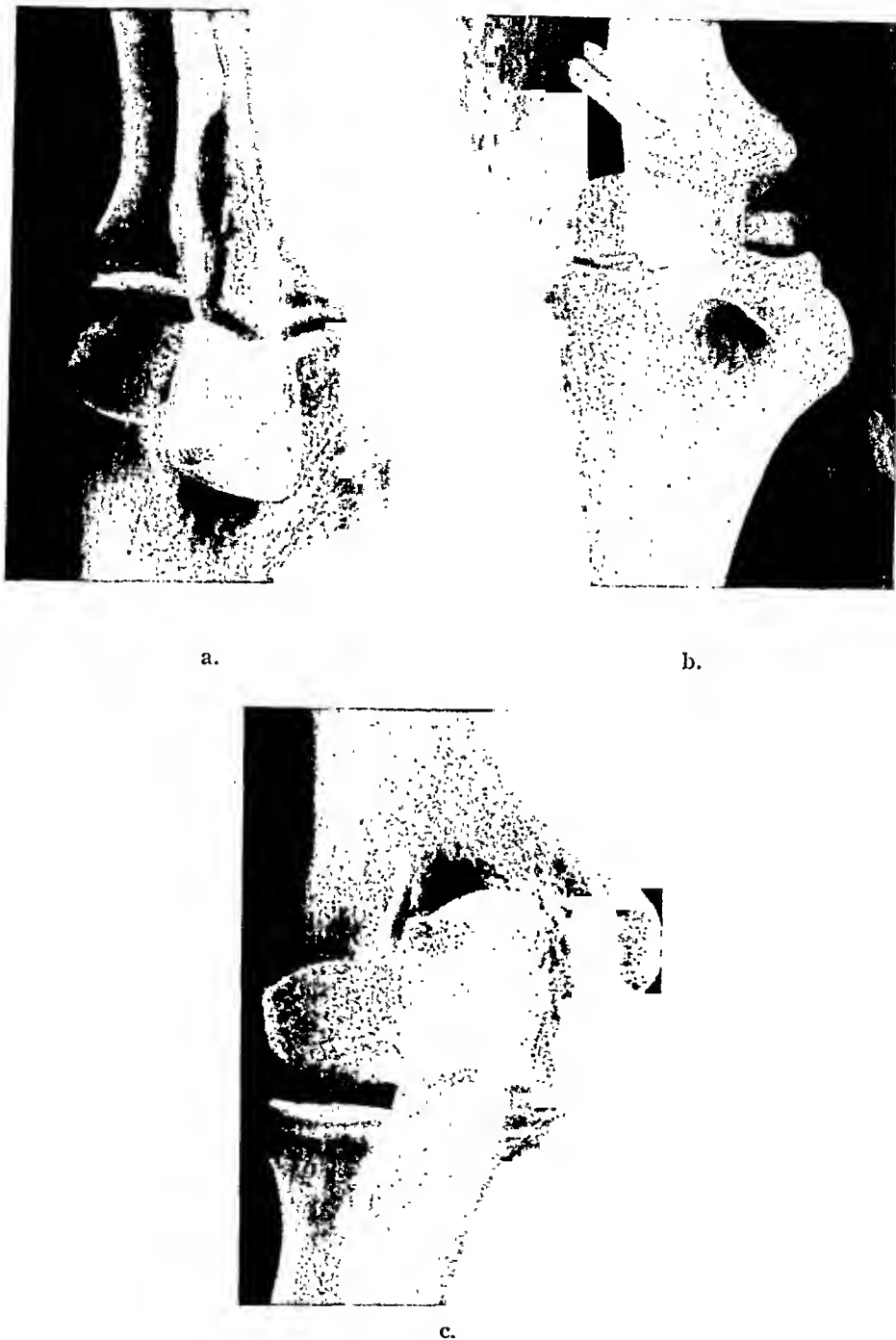


Fig. 3.

A.G. aged 10 years. a. Fracture of the neck of the radius.  
 b. 10 years later: "new capitulum".  
 c. healthy side for comparison.

In cases of fracture of the neck in children, where the head has been reduced, complete recovery—judging by the radiographs—may result, and an example of this is given in Fig. 4.

Arthrosis deformans changes are quite frequently seen on the radiographs, following fractures of the head of the radius. In this material such changes have been observed in 28 out of 69 cases (41 per cent.). The period of observation for the group in which these changes were detectable was, on an average, 9 years, and the average age of the patient was 40 years. The corresponding figures for the group without changes were 7 and 36 years. This suggests the possibility that by



c.  
*Fig. 4.*

B.V. aged 8 years. a. Fracture of the neck with considerable displacement.  
b. appearance 6 years later.  
c. healthy side for comparison.



prolonging the observation period, further instances of arthrosis deformans may develop; the difference is, however, very small and it can be presumed that in many cases of fracture of the head of the radius, such changes do not develop. A significant difference in the incidence of arthrosis deformans has not been demonstrable in the types of fracture or methods of surgical treatment. As mentioned previously, by, for example, *Baumann*, it is remarkable that no correspondence exists between the symptoms and radiologically demonstrable arthrosis deformans; even in cases where this is very pronounced, the patient is invariably symptom-free.

#### SUMMARY

Seventy-four cases of surgically—treated fresh fractures of the head of the radius were re-examined on an average 8 years after the injury, and the results of treatment have been judged in accordance with the type of fracture and the method of operation.

A fracture of the head of the radius comprises simultaneous injury to the bone, capsule and soft tissue in and around the elbow. Luxation or sub-luxation occur in most cases, but these are often spontaneously reduced.

The prognosis depends mainly on the type of fracture.

In cases of marginal fractures with displacement, and comminuted fractures, where it is possible to choose the method of operation, the results following total excision and removal of the fragment are not appreciably different.

Where total excision is performed, this should include the greater part of the neck as well as the head of the radius.

Following total excision, changes such as cubitus valgus and proximal displacement of the radius, with consequent changes at the wrist, are very frequent, but only in a few cases do they cause symptoms, except where the excision is performed in children.

In cases of marginal fractures with moderate displacement, open reduction, when it is possible, gives satisfactory results, and it should perhaps be used more than formerly.

## RESUME

Soixante-quatorze cas de fractures de la tête du radius traitées chirurgicalement pendant qu'elles étaient fraîches ont été réexaminées en moyenne 8 ans après la lésion et les résultats du traitement ont été jugés en se basant sur le type de fracture et la méthode d'opération utilisée.

Une fracture de la tête du radius comporte simultanément la lésion de l'os, de la cupule et des tissus mous qui entourent le coude. Dans la plupart des cas il se produit une luxation ou une sub-luxation, qui disparaissent souvent spontanément.

Le pronostic dépend principalement du type fracture.

Dans les cas de fractures marginales avec déplacement, et de fractures broyées, où il est possible de choisir la méthode opératoire, les résultats suivant l'excision totale et l'extirpation du fragment ne sont pas sensiblement différents.

Lorsque l'excision totale est pratiquée, elle comprend une grande partie du col et de la tête du radius.

A la suite de l'excision totale, des modifications telles que le cubitus valgus et le déplacement proximal du radius, avec les modifications qui s'ensuivent dans le poignet sont très fréquentes, mais ne provoquent des symptômes que dans très peu de cas, excepté lorsque les excisions sont faites chez des enfants.

Dans les cas de fractures marginales avec léger déplacement, une réduction ouverte, lorsqu'elle est possible, donne des résultats satisfaisants et devrait peut-être être pratiquée plus souvent que cela n'a été le cas jusqu'ici.

## ZUSAMMENFASSUNG

Vierundsiebzig Fälle von chirurgisch behandelten, frischen Brüchen des Radiusköpfchens wurden im Durchschnitt 8 Jahre nach dem Unfall nachuntersucht und das Resultat wurde entsprechend der Bruchtype und der Operationsmethode beurteilt.

Ein Radiusköpfchenbruch umfasst gleichzeitige Schädigung des Knochens, der Kapsel und der Weichteile im und um das

Ellbogengelenk. Luxation und Subluxation treten in den meisten Fällen auf, aber renken sich meist spontan ein.

Die Prognose hängt zum grössten Teil von der Bruchtype ab.

In Fällen von marginalem Bruch mit Verschiebung und in Splitterbrüchen, wo es möglich ist die Operationsmethode zu wählen, zeigen die Resultate nach Excision und Entfernung des Fragmentes keine wesentliche Verschiedenheit.

Wo die totale Excision ausgeführt wird, sollte sie stets sowohl den grösseren Teil des collum radii als auch des capitulum mit inbegreifen.

Nach der totalen Excision sind Veränderungen, wie cubitus valgus und proximale Verschiebung des Radius mit folgenden Veränderungen des Handgelenkes sehr häufig. Aber nur in wenigen Fällen rufen sie Symptome hervor, ausgenommen jene Fälle in welchen die Excision an Kindern vorgenommen wurde.

In Fällen von marginalen Brüchen mit geringer Verschiebung giebt die offene Reposition, wenn sie ausgeführt werden kann, zufriedenstellende Resultate und sollte vielleicht häufiger angewendet werden.

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## CONGENITAL COXA VARA AND PERTHES' DISEASE

By

CASPAR LIAN

Congenital coxa vara is a rare condition of unknown etiology. In a recent survey from two large clinics in North America, the present author reported that only 15 cases were registered over a period of 20 years (1).

Of these 15 cases, 7 were boys and 8 girls. The right side was affected in 9, the left in 2, and both sides in 4.

The etiology, as already mentioned, is unknown, but in the above survey it is suggested that probably the most acceptable theory is a *disturbance of the vascular supply of the femoral neck during embryonic life*. J. F. Brailsford gives as his personal view the theory that it is caused by a *dysostosis*,—a developmental defect in the zone of ossification (2).

The diagnosis must in most cases be based on the radiographic examination. Clinically, there is a history that the child has limped since it began to walk. The limp is similar to that seen in congenital luxation of the hip, but clinical examination shows that there is no telescoping and the head is in the acetabulum.

In the radiographs the most important criteria for the differential diagnosis are the appearance and direction of the epiphyseal line. In congenital coxa vara the line is vertical and is often divided in its lower part to form an inverted Y (1).

Halfdan Sundt, in his paper on the "Malum Coxae Calvé-Legg-Perthes", describes the same criteria when he writes of "the vertical, broad and often fork like divided epiphyseal

line", and later on he writes of the "lower corner of the neck being rounded off" (3).

This appearance is very different from that seen in rachitic coxa vara, where the epiphyseal line is oblique and has an edge-like prominence of the lower corner of the femoral-like neck.

Perthes' disease, or coxa plana, occurs rather frequently in boys, and its pathological and clinical picture is much better known. Here I will concentrate on the changes seen in this condition in the neck of the femur, distal to the epiphyseal line.

According to *Sundt's* description the changes in the neck in Perthes disease are found in the upper corner. There are osteoporosis and a number of osteochondritic foci surrounded by a sclerotic zone.

The appearance of the neck changes; it becomes broad and clumsy, but the *direction* of the epiphyseal line does not change—especially it does not become more vertical; rather, it appears to go the other way and, in fact, the result is a slight displacement of the head in a *valgus* position. This is due to the broad and deformed shape of the neck.

In *Sundt's* paper a wide variety of changes is described, and of particular interest for this article is his statement that Perthes' disease has been observed to develop in cases of pre-existing congenital coxa vara. It has not been specified that the osteochondritic changes tend to appear in the neck in predisposed cases of congenital coxa vara. In only one case were there changes compatible with Perthes' disease in both head and neck. (3).

After this introduction, a case is presented which has been observed in Farsund Hospital for 9 years, from 1940 to 1949, when the final treatment was begun.

L.B. was aged 7 years when he was admitted to hospital on 2.26.40 with a history of limping on the R. lower limb since he began to walk. The right leg appeared to be shorter than the left one. He never had any pain or discomfort, and had therefore never been examined by a

doctor until now, when he had had an accident on a sledging hill. He received a blow on his right hip and a scalp wound, which was sutured. He was then sent to hospital for radiography of his hip.

Clinically, there was marked shortening of the R. leg with a high trochanteric prominence. There was no pain on movement, but there was limitation of internal rotation, abduction and flexion. Otherwise, nothing of importance was found.

The radiographs of 2.26.40 are shown in fig. 1. There is a R. coxa vara with osteochondritic changes in the upper corner of the neck; the left hip appears to be normal.



*Fig. 1.*

The epiphyseal line is vertical on the affected side; it is wide, and the lower corner of the neck is rounded-off.

The diagnosis made at this time was that of an atypical case of Perthes' disease, drill holes were made through the neck into the head, apparently without any beneficial effect, as can be seen from the following radiographs. These show that the coxa vara persisted, or rather progressed, and led to the development of a deformed head, which gradually became displaced distally in relation to the neck, with a wide and open epiphyseal line. Osteochondritic changes are seen in the upper corner of the neck; these gradually disappeared, but in its course the condition followed the typical pattern of Perthes' disease (figs. 2 and 3).

The patient returned for periodical examination and radiography until March 1943, when, due to the circumstances in Norway at that time, he disappeared.

He was not seen again until February 1949, when he was re-admitted to the Hospital, suffering from drug poisoning. On this occasion he was re-examined for his hip condition with the following report:

"The patient is a well-developed boy aged 15 years, with an obvious



limp on the right side, where the trochanteric prominence is high. There is a positive Trendelenburg sign with shortening and atrophy of the R. lower limb and marked limitation of abduction, internal rotation and flexion at the hip."



*Fig. 2.*



*Fig. 3.*

Radiography on 2.12.49 showed a wide space at the site of the epiphyseal line, with a high position of the neck and major trochanter. The head was deformed, with a protruding lower lip, but the articular surface and space were well preserved. The changes seen earlier in the upper corner of the neck had completely disappeared (fig. 4).

The patient was treated in bed with moderate traction on the R. lower limb. Repeated radiography during this period showed the develop-

ment of a pseudarthrosis at the site of the epiphyseal line, where there was definite movement between the head and neck.



*Fig. 4.*

From the patient's story, the clinical examination and the radiographic appearance, it was concluded that the original diagnosis only covered one of the conditions present. The diagnosis was revised to one of congenital coxa vara with secondary changes in the neck, identical with those seen in Perthes' disease.

The unilateral involvement and the radiographic appearance both fail to conform to the picture of rachitic coxa vara.

The treatment of congenital coxa vara has been discussed, and it has been said that subtrochanteric osteotomy, with abduction of the distal fragment, is the procedure of choice. By this operation one can obtain a more oblique direction of the epiphyseal line with a tendency to "impaction of the fragments", which should promote healing and prevent pseudarthrosis. This treatment often promotes healing in children, but in the present case there was already a well-established pseudarthrosis, and we could not expect any beneficial effect from it alone.

An operation was therefore performed in two stages. At operation we found the pathology we expected.

The following operation was performed under general anaesthesia, by the author, on 23.3.49.

1. *Resection of the pseudarthrosis—Bone transplantation—Screwing.*

Using a Smith-Petersen incision, the R. hip was exposed and the joint was opened anteriorly. As seen on the radiographs there was a pseudarthrosis with articular surfaces covered by smooth cartilage on both ends. The pseudarthrosis was open on the proximal-anterior surface, but covered on the distal-posterior surface by strong ligamentous bands. On movement the head glided on the rounded surface of the neck.

The pseudarthrosis was resected, and bone chips from the ilium were plugged into the open space between the denuded ends of the head and neck. The head was then fixed by a vitallium screw through the long lower edge of the neck into its central part. The fixation appeared to be firm when tested by movement at the joint. The wound was closed, and light traction was again applied.

5 weeks after the first operation, there was evidence of union at the site of the resection and the position was unchanged (fig. 5).



Fig. 5.



Fig. 6.

At a second operation the following procedure was completed:

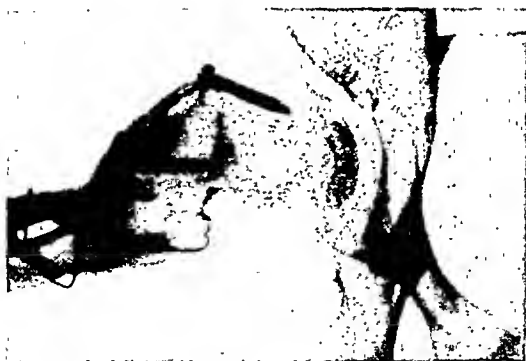
2. *Subtrochanteric Osteotomy-Osteofixation-Hip spica.*

A lateral (Badgley) incision was made, starting 1 inch behind the anterior superior spine and curving down behind the trochanteric prominence and along the posterior aspect of the femur, which was exposed just below the lesser trochanter. At this site an osteotomy was per-

formed with removal of a triangular piece of bone with its base laterally. By this procedure the distal fragment was opposed to the proximal in marked abduction; an angulated Soyland's plate was then fixed to the



*Fig. 7 a.*



*Fig. 7 b.*

fragments which were in close contact with each other. After closure of the wound a half hip spica was applied.

There were no complications after either operation and the cast was bivalved after 8 weeks, when there was radiographic evidence of union (fig. 6).

During the following 4 weeks the patient was doing quadriceps-exercises, and flexion of the knee was allowed. After this period the pro-

gramme was intensified, and 13 weeks after the second stage he was up on crutches with a good range of movement at the hip.

4 months after the second stage operation he was re-examined. At this time he was ambulatory. He was still using a stick and walking with a slight limp. He did not notice any pathological movements, and spontaneously remarked that its absence felt very peculiar, as he had been used to it for so many years. There was no pain or feeling of instability in the R. lower limb.

Clinical examination gave the following report:

Trendelenburg's sign: Neg.

There is  $\frac{1}{2}$  inch real and apparent shortening of the R. lower limb.

There is 2 inches atrophy of the leg and 1 inch of the R. calf.

Range of R. hip movements: No contracture. Flexion  $135^{\circ}$  ( $155^{\circ}$ ). Abduction  $20^{\circ}$  ( $30^{\circ}$ ). Adduction  $30^{\circ}$  ( $25^{\circ}$ ). Internal rotation  $20^{\circ}$  ( $25^{\circ}$ ). External rotation  $30^{\circ}$  ( $30^{\circ}$ ).

Thus, only the slight limitation of flexion and abduction are of practical importance.

Radiography on 9.1.49 (fig 7) showed sound union at both sites, with a good static position. No evidence of secondary changes in the head as yet, but for this reason the patient will have to be kept under close observation and radiographic control for a long period.

The case is considered to be of considerable diagnostic and therapeutic interest and it is therefore presented at this early post-operative stage.

### SUMMARY

A case of congenital coxa vara complicated by osteochondritic changes in the neck identical with those occurring in Perthes' disease is reported with a complete radiographic follow-up. The case has been followed for 8 years; during this time a pseudarthrosis developed in the neck and was treated by a two-stage operation. First, the pseudarthrosis was resected, bone chips were transplanted from the ilium, and the head and neck were fixed with a screw. Later, a subtrochanteric osteotomy was performed, with a resulting good position of the femoral neck.

### RESUME

Un cas de coxa congénital compliqué d'altérations ostéochondritiques dans le col fémoral, identiques à celles appa-  
r-

sant dans la maladie de Perthes est rapporté avec une série complète de radiographies. Le cas a été suivi pendant 8 ans; pendant cette période une pseudarthrose s'est développée dans le col et a été traitée par une opération en deux phases. Dans la première, résection de la pseudarthrose; des fragments de l'os iliaque ont été transplantés la tête et le col ont été fixés au moyen d'une vis. Plus tard une ostéotomie subtrochantérique a été pratiquée et il en est résulté une bonne position du col fémoral.

#### ZUSAMMENFASSUNG

Ein Fall von angeborener coxa vara mit komplizierenden osteochondritischen Veränderungen in collum femoris, identisch mit den Veränderungen bei Perthes'scher Krankheit, wird mitgeteilt zugleich mit einer kompletten röntgenologischen Verfolgung des Falles. Die Beobachtung wurde 8 Jahre hindurch fortgesetzt. Während dieser Zeit entwickelte sich eine Pseudarthrose im Femurhals, die mit Operation in zwei Sitzungen behandelt wurde. Zuerst wurde die Pseudarthrose reseziert und gleichzeitig Knochenstückchen transplantiert und eine Schraubenfixation vorgenommen. Später wurde eine subtrochantäre Osteotomie ausgeführt, die in einer guten Position des Femurhalses resultierte.

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## A CASE OF SPONDYLOLISTHESIS LUMBALIS ACQUISITA

By

LARS UNANDER-SCHARIN, M.D.

Spondylolysis is a break in continuity in the pars interarticularis of a neural arch. Spondylolisthesis occurs when the ends of the bone glide apart at this break in continuity, and the vertebral body, with the anterior part of the arch and the superior articular processes and all the spinal column above it, slips forwards.

During the 19th century, spondylolysis was regarded as being a very rare complaint of women; but it has since been shown, partly by radiographic investigations, that it occurs relatively frequently, and almost as often in men as in women. The frequency of spondylolysis is given as approximately 5 % (*Neugebauer, Waldeyer, Willis, Friberg*). It should be remembered, however, that most of the information concerning its frequency is based on hospital material. Probably most cases of spondylolisthesis and spondylolysis do not give any symptoms and have therefore never been diagnosed.

A purely theoretical differentiation has been made between *congenital, acquired* and *traumatic* spondylolysis and spondylolisthesis.

Many authors have regarded the condition as congenital (*Willis, Neugebauer, Schmorl, Junghans, Friberg, Brocher, Turner*), in view of the fact that it is found in children. 2 ossification zones were thought to occur in the vertebral arch, instead of the normal one. After *Friberg's* work we may now consider it proved that spondylolysis can be a congenital deformity, and that it is so in the majority of cases.

*Lane*, and later *Meyer-Burgdorff*, favoured the view that all spondylolyses are acquired. They believed that the articular processes of the spines lying above and below it can produce "eine chronische Umbauzone" on the interarticular portion as a result of constant pressure. This would occur particularly when the back was subjected to abnormal strain as for instance with a gibbus deformity after a fracture, in pregnancy and with severe strains of the back. The authors have not shown any proof that this really occurs nor, in fact, that there is any such thing as acquired spondylolysis.

*Jaeger* attributes spondylolisthesis acquisita to metastases or to aseptic necrosis of the bone in the pars interarticularis.

Frank traumatic spondylolyses in connection with great violence have been described, but they have then always been combined with subluxation, luxation or compression fractures of one or more vertebrae, usually with compression of the spinal cord (*Friberg, Böhler, Watson-Jones, Aschan* and others).

"Traumatic spondylolisthesis" without other changes has been described by *Kleinberg, Böhler* and *Steiner*. In support of their traumatic origin these authors point out that trauma was reported in the history. In *Steiner's* case there was a "fracture" with jagged bone ends of the pars interarticularis. In none of the cases had radiographs of the back been taken before the injury, and therefore the traumatic origin cannot be considered to be proved.

*Roberts, Königstein, Gerlach, Turner* and *Markellow* made experimental investigations on corpses. They could not cause spondylolysis, even when considerable violence was used. *Turner* and *Makellow* wrote: "das geht unzweifelhaft hervor, das es keine traumatischen Spondylolysen gibt" and *Gerlach* says: "auch durch maximalste Überstreckung der Lendenwirbelsäule in Sinne der Lordose und Kyphose ist es nicht gelungen, weder einseitige noch beidseitige Frakturen im Bereich der Interartikularportion, auch nicht durch stärkste Gewalt-einwirkung zu erzeugen".

Thus, in spite of considerable clinical and experimental



investigations of spondylolysis, only its congenital origin has been proved. The occurrence of acquired and traumatic spondylolysis has not yet been proved.

However, spondylolisthesis in a previously normal vertebral arch has occurred at the Orthophaedic Clinic of the Karolinska Institute in Stockholm.

*Case No. 3835/38*, a female hospital employee, born 1905. Attended the clinic for the first time in 1938, when she complained of her back. She had had increasing pain and a feeling of tiredness in her back for the past two years. Her condition was temporarily improved by massage and the use of a corset. Despite conservative treatment, however, she grew gradually worse; she found it difficult to perform her duties and was confined to bed from time to time.

*Examination 1938*. General condition good, tall and heavily built, Normal configuration and mobility of the back; she complained of intense throbbing pain in the lower lumbar region. Laségue negative bilaterally. No abnormal neurological findings.

*Radiography in 1938*, no abnormality in the lumbar region. *In 1943*, signs of degeneration in the 4th lumbar disc: diminished interspace, slight ante-position of the lumbar vertebra and lack of stability during functional tests. (Fig. 1).

1944, lumbar osteosynthesis performed on account of the severe complaints which resisted all conservative therapy; and because of an apparent disc degeneration. A tibial transplant was placed unilaterally on the resected arches of the 3rd, 4th and 5th lumbar vertebrae and sacrum. In addition, plentiful bone chips were inlaid on both sides of the spinous processes.

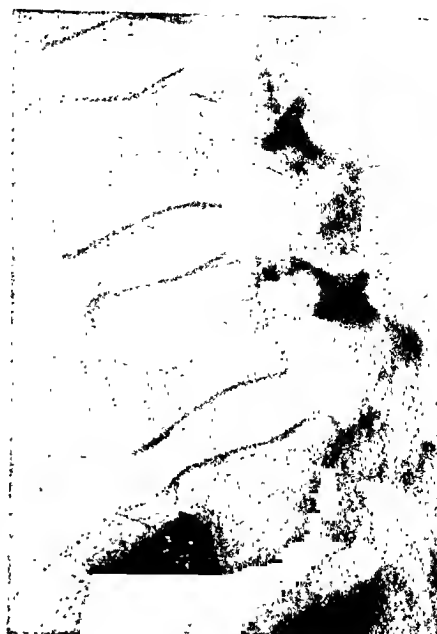
*Progress*: The patient was kept in a plaster bed for ten weeks and in a plaster jacket for three months. Six months after the operation she was free from symptoms, and radiography showed that the osteosynthesis had consolidated and that there were no changes in the condition.

We did not hear from her again until January, 1949, when she was asked to come for follow-up examination. She then said that during the first year after the operation she had been free from symptoms but then her original complaints had returned. She had tried to take up her previous employment as a hospital employee but could not do so.

Objectively there was a normal configuration of the back: but minimal mobility in the lumbar region. When she bent forwards she had to support herself with her hands on her knees in order to prevent herself from falling over. Pressure in the region of the upper end of the osteosynthesis caused throbbing pain. Laségue negative bilaterally. No neurological abnormalities.



*Fig. 1 a.*



*Fig. 1 b.*



*Fig. 1 c.*

*Fig. 1 a.* 1943 (before operation). The back in normal position. The intervertebral space between the 4th and 5th lumbar vertebrae is slightly reduced.

*Fig. 1 b.* 1943 (before operation). The back in forward bending position. Besides the reduced space between the 4th and 5th lumbar vertebrae, there is a displacement forward of the 4th lumbar as a sign of instability of the 4th intervertebral disc.

*Fig. 1 c.* 1943 (before operation). Radiograph taken obliquely from behind in order to show the pars interarticularis of the neural arch.



*Fig. 2 a.*



*Fig. 2 b.*



*Fig. 2 c.*

*Fig. 2 a.* 1949 (5 years after operation). The back in backward bending position. Bilateral spondylolysis on the arch of the 3rd lumbar vertebra. Reduced space between the 3rd and 4th lumbar vertebrae. The osteosynthesis shows satisfactory bone block formation.

*Fig. 2 b.* 1949 (5 years after operation). The back in forward bending position. The 3rd lumbar vertebra is anteposed and the diastasis at the spondylolysis has increased.

*Fig. 2 c.* 1949 (5 years after operation). Radiograph taken obliquely from behind, showing the bilateral spondylolysis and the osteosynthesis.

Radiography showed a block of bone between the arches of the 3rd, 4th and 5th lumbar vertebrae and the sacrum. The transplant was well consolidated, but on the arch of the 3rd lumbar vertebra there was a bilateral spondylolysis, which had a typical interarticular columnar formation on both sides. Further, there was evidence of degeneration of the 3rd lumbar disc with diminished interspace. When she bent forwards, there was anteposition of the 3rd lumbar vertebra and the diastasis of the spondylolysis increased. When she leaned backwards, the 3rd lumbar vertebra resumed its normal position and there was contact between the bone surfaces of the spondylolysis (see Fig. 2).

Thus in this case a satisfactory fixation of the degenerated 4th lumbar disc was obtained: but a spondylolysis of the 3rd lumbar vertebral arch and a degeneration of the 3rd lumbar disc developed. The complaints which began one year after the operation, might be regarded as due to the spondylolysis. There is no record of any accident or over-straining of the back after the operation. The radiographs, which were taken with infinite care and from various projections, categorically exclude the possibility that the changes were present either before the operation or when the patient was re-examined six months after it.

It cannot be determined whether the degeneration in the 3rd disc preceded the spondylolysis and predisposed towards it, or whether it followed it. One knows that destruction of the underlying disc takes place in most cases of spondylolisthesis (*Schmorl* and *Junghans* and others). On the other hand, the degeneration in the 3rd disc might have been present before the operation, although not visible on the radiographs. Therefore, the spondylolysis was thought to be secondary to the degeneration and related to the severe strain to which it had been subjected.

Abnormal strain on the spinal column always follows osteosynthesis. The osteosynthesis, especially if it has been extensive, is itself subject to severe strain, which in many cases leads to fracture and "umbauzone" with residual pseudoarthroses (*Odelberg-Johnsen*, *Alvik*, *Bierring*, *Unander-Scharin* and others). In the case under review the strain did not cause a fracture of the osteosynthesis, but instead there was a break

in continuity in the arch of the uppermost spine of the osteosynthesis.

This is a highly interesting case, partly because, as far as the author can discover, it is the only definite case of acquired spondylolysis, and partly because it is the only reported case of spondylolysis following spinal osteosynthesis. Anyway, we can now say that not only congenital but also acquired spondylolysis has been proved to occur. It now remains to prove the occurrence of traumatic spondylolysis.

#### S U M M A R Y

The author describes a case of spondylolysis of the vertebral arch of the 3rd lumbar vertebra, which had been shown to be normal at three previous examinations. The spondylolysis was observed 5 years after an osteosynthesis involving the 3rd, 4th and 5th lumbar vertebrae and the sacrum. The osteosynthesis was performed for pain in the back associated with radiographic signs of degeneration of the 4th lumbar disc.

#### R E S U M E

L'auteur décrit un cas de spondylolyse de l'arc vertébral de le 3ème vertèbre lombaire qui avait été trouvée normale à trois examens antérieurs. La spondylolyse a été observée 5 ans après une ostéosynthèse atteignant les 3ème, 4ème et 5ème vertèbres lombaires et le sacrum. L'ostéosynthèse a été à la suite de douleurs lombaires associées à des signes radiographiques de dégénération du disque de la 4ème vertèbre lombaire.

L'auteur n'a pas trouvé de cas similaire décrit dans la littérature. Ce cas présente un très grand intérêt, parce que c'est la seule description que l'on ait d'une spondylolyse acquise et la seule qui se soit produite à la suite d'une ostéosynthèse lombaire.

## ZUSAMMENFASSUNG

Der Verfasser beschreibt einen Fall von Spondylolysis des Wirbelbogens des 3. Lendenwirbels, der bei drei vorhergegangenen Untersuchungen normal erschien. Die Spondylolyse wurde 5 Jahre nach einer Osteosynthese des 3., 4., 5. Lendenwirbels und des os sacrum beobachtet.

Es war dem Verfasser nicht möglich einen ähnlichen Fall in der Litteratur aufzufinden. Der Fall ist sehr interessant da er die einzige Beschreibung einer erworbenen Spondylolysis darstellt und der einzige ist, der nach lumbaler Osteosynthese aufgetreten ist.

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## BENIGN GIANT CELL TUMOUR OR LOCALISED OSTEITIS FIBROSA CYSTICA

BY

BERTIL LARWIK

The name applied to this case may be disputed, since a variety of names has been used in the past for the condition now called *Giant cell tumour*, viz.: *benign giant cell sarcoma*, *giant cell tumour*, *primary giant cell tumour*, *endosteal myeloid sarcoma*, *myeloid disease*, *myeloid sarcoma*, and *osteoclastoma*. According to Fleischer-Hansen the conceptions of benign giant cell tumour and of localised osteitis fibrosa have varied widely. However, thanks to improved radiographic technique in the last few years, certain, fairly well-defined, clinical types have been recognised. At the outer limits are bone cysts, which may be regarded as a form of localised osteitis fibrosa, on the one hand, and the true benign giant cell tumours on the other. Also at certain sites transitional conditions, e.g. localised osteitis fibrosa, which are difficult to differentiate from a benign giant cell tumour containing cysts, do occur and make a definite diagnosis difficult.

Benign giant cell tumours usually occur at the end of one of the long bones, particularly at the distal end of the femur and the proximal end of the tibia. This case is only reported because of its site—which has been reported 21 times in the literature.

E.G.O. A woman, born 28.11.17. Admitted to hospital 12.11.45. Complained of pain in the R. knee anteriorly and of occasional instability in the knee on walking. The trouble began in June 1945 when the patient was kicked on the R. knee by a cow. The knee swelled rapidly,



but the swelling disappeared in a few days with hot compresses. The knee had given no previous trouble.

O.E. Palpable, but not measurable, atrophy of the thigh muscles. Circumference at 15 cm. above the upper patella border was 44 cm. on both sides. Reduced elasticity of the muscles. No swelling or heat. No deformity. Slight tenderness over the medial border of the patella. Full active movement. Small retropatellar crepitations. Pain felt under the patella when it was compressed against the condyle.

*Left knee.* Small retropatellar crepitations, otherwise nothing abnormal.

Blood: Serum calcium 11.7 mg. per cent.

Phosphatase 3.5 units.

Hb 82 %.

R.B.C. 4,740,000.

Sed. Rate 8 mm.

Blood Wasserman Reaction: positive.

31.11.45. "Radiography shows thinning at the medial border of the patella; the cause cannot be determined. It is most suggestive of localised osteitis fibrosa". (signed) R. M. (Fig. 1).

26.11.45. "Radiography of pelvis, hips, femora, tibiae and fibulae, and of the upper limbs shows no definite signs of osteitis fibrosa". (signed) R. M.

These radiographs were taken to exclude the possibility that the changes in the patella were part of a generalised osteitis fibrosa. The calcium concentration and the phosphate values were also against this diagnosis. The other possible diagnosis was a syphilitic infection, in view of the positive WR. The differential diagnosis could not be carried further without a biopsy.

16.11.45. *Curettage of the bone tumour in the patella.* As soon as the tendon fibres on the patella were freed, a bluish colour could be seen; the anterior layer of bone came away when an attempt was made to separate off the tendon. Almost immediately one came onto a cavity filled with a grey-brown mass. The opening in the patella was widened, and the tissues filling the hole, which was about the size of a hazel-nut, were scraped out. The walls of the hole were sclerotic and firm; here and there there were ridge-like projections. The only opening was near the ligamentum patella. The soft parts were sutured.

*Pathological Investigation.* The ground substance consisted of numer-



*Fig. 1.*

Lateral view of patella before operation.

ous regular multinucleate giant cells of epulis type. There was also plentiful blood pigment, and individual fragments of necrotic bone. The picture appeared benign.

Diagnosis: Localised osteitis fibrosa, or benign giant cell tumour (A. L. Fig. 2).

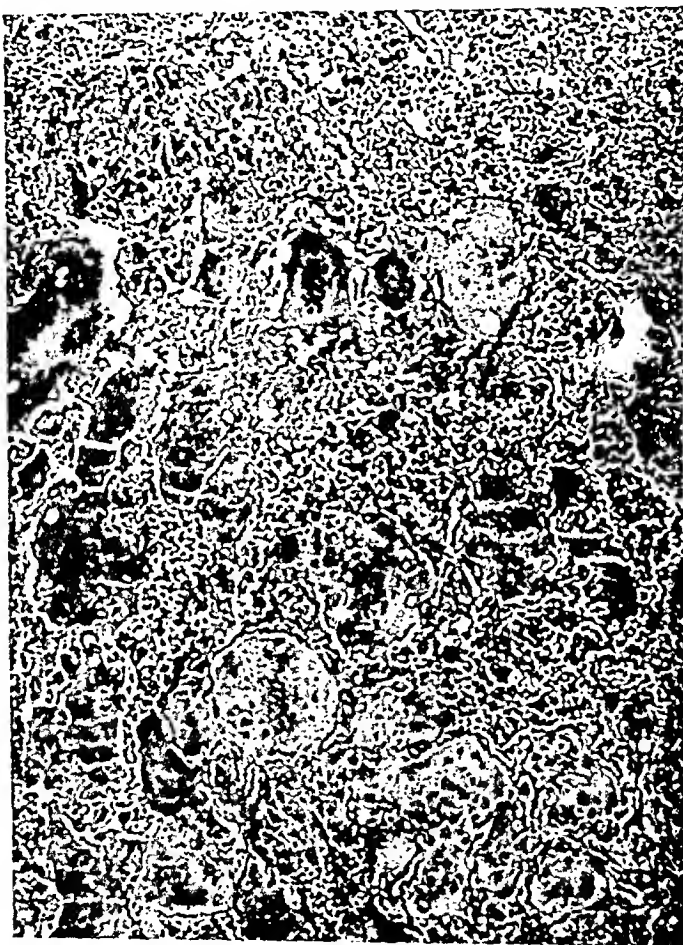
28.11.45. The patient returned home, walking quite well; able to bend the knee to 90°.

5 of the 21 cases in the literature were treated by curettage; in 2 the condition recurred. The present case has been followed for 3½ years.

17.6.46: *Reports* continued improvement. Walks well on flat ground; can walk for over a mile. Has difficulty in kneeling on the knee. Pain

across the R. knee when she sits for a long time with the knee flexed. No stiffness in the morning. Sometimes pain on walking upstairs. No spontaneous pain; no swelling.

*O. E.* R. knee. Palpable, but not measurable, atrophy of the thigh muscles. Circumference 15 cm. above the upper border of the patella



*Fig. 2.*

Microscopic picture of resected material.

47 cm. on both sides. No swelling. Full active extension and flexion. Bilateral small, retropatellar crepitations on extension. Normal gait.

*Radiography:* "The operation cavity has been considerably filled in with bone tissue" (signed) O. O. (Fig. 3).

*5.6.47: Reports* she is better than at the last examination. Walks

unchanged. No swelling. Full active flexion and extension. Small bilateral retropatellar crepitations. Gait N. A. D.

*Radiography:* "Comparison with the radiograph of 17.6.46 shows further bone formation in the cavity. Only a small cavity, the size



*Fig. 3.*

Lateral view of patella immediately after operation.

well in rough country for over a mile. No difficulty in going up stairs. May still have some pain from the knee after sitting for a long time with the knee flexed (e.g. at a cinema). No stiffness in the mornings. No spontaneous pain. No swelling.

*O. E. R. knee.* No atrophy of the thigh muscles, and circumference of a pea, remains in the medial part of the patella. Otherwise the bone outline of the patella is well-defined". (signed) O. O.

*12.7.49: Reports* that she feels almost cured. No difficulty in walking on rough ground or on stairs. Occasionally she has slight discomfort after sitting for a long time with the knee flexed. No stiffness in the morning. No swelling; no spontaneous pain.

O. E. No atrophy of the thigh muscles. Measurements unchanged. Full active extension and flexion. No swelling. Small bilateral retropatellar crepitations. Gait: N. A. D.

*Radiography:* "Comparison with previous picture shows further bone formation in the cavity, of which only an insignificant remainder persists. There also appears to be slight periosteal bone formation". (signed) O. O. (Fig. 4).



Fig. 4.

Lateral view of patella 3½ years after operation.

In the embryo the patella passes through pronounced pre-cartilaginous and cartilaginous phases in its development. *Geschichter* and *Copeland* found that giant cell tumours occur exclusively in bone which originates embryologically from cartilage. They believe that this type of tumour is caused by trauma to the cartilaginous bone. The trauma damages

the periosteal blood vessels, and the result is a reduced blood supply to part of the bone. They have also suggested that the tumour represents a local overstimulation of osteoclastic activity, which has caused a revascularisation of the part. They have stressed earlier that benign giant cell tumours occur in places where the spongiosa is relatively soft, as in the proximal part of the tibia. When there is considerable mechanical resistance to its growth, as in the solid cortical bone of the shaft of the femur, it remains as a localised osteitis fibrosa containing many giant cells. This theory agrees well with the finding of these tumours in the patella, which has hardly any cortex and is virtually all spongiosa.

From the point of view of insurance, it is of great interest to know how far trauma can be regarded as influencing the occurrence of the tumour, especially as, according to the literature, it affects mainly those between 28 and 30 years. Trauma seems to have occurred in 19 out of the 21 cases in the literature, but one must not, of course, attribute too much importance to this, since the patella is often injured without any persisting symptoms arising. Further, one would expect the tumour to occur more often, if trauma was the cause. The trauma appears to occur usually from weeks to years before any symptoms appear. In fact, it is doubtful whether trauma can really be regarded as predisposing to this condition.

The Americans insist upon routine resection of the patella in cases of benign giant cell tumour for two reasons. Firstly, relapses do occur; secondly, it is, according to *Geschichter* and *Copeland*, difficult to distinguish it radiographically, or even microscopically, from malignant conditions.

Nevertheless, curettage was used in this case in order to save the patella, if possible. So far, the follow-up examination has given rise to no fear of relapse or malignancy. A prerequisite for the use of this less mutilating operation is, of course, that the curettage is sufficiently extensive and is carried into healthy bone, and that the patient is followed up.

## SUMMARY

1. The commonest age for benign giant cell tumour is 28-30 years.

2. In 20 out of the 22 published cases trauma was regarded as a predisposing factor.

3. The occurrence of benign giant cell tumour in the patella agrees with the theory that this tumour develops only in spongiosa bone, which embryologically arises from cartilage.

4. This case, in which the less disabling curetting operation was used, does not give any support for the American view that the resection of the patella should be routine in these cases.

5. If the curetting method is used, the case must be followed up for at least 3 years, in view of the risk of recurrence and malignant degeneration.

## RESUME

1. L'âge le plus commun pour l'apparition de tumeur bénigne à cellule géante est 28—30 ans.

2. Dans 20 des 22 cas publiés, un traumatisme était considéré comme un facteur prédisposant.

3. L'apparition de tumeur bénigne à cellule géante dans la rotule concorde avec la théorie que la tumeur ne se développe que dans les os spongieux qui embryologiquement des cartilages.

4. Ce cas, dans lequel on a procédé à un curettage, c'est-à-dire à une opération moins radicale; n'appuie absolument pas la théorie américaine suivant laquelle il convient de procéder à la résection de la rotule.

5. Si l'on recourt au curettage, le cas doit être minutieusement suivi, au moins pendant 3 ans, en raison des risques de rechute ou de dégénération maligne.

## ZUSAMMENFASSUNG

1. Das gewöhnlichste Alter für den gutartigen Riesenzellentumor ist das 28.—30. Lebensjahr.

2. In 20 der bisher beschriebenen 22 Fälle wurde das Tauma als prädisponierender Faktor angesehen.

3. Das Vorkommen von gutartigen Riesenzelltumoren in der patella stimmt gut überein mit der Theorie, dass diese tumoren ausschliesslich in spongiösem Knochen vorkommen, der embryologisch vom Knorpel abstammt.

4. Ein Anhaltspunkt für die von Amerikanern stereotypisch anbefohlene Patellarresektion liegt nicht vor in diesem Fall und man bevorzugt hier die weniger verstümmelnde Curettagetechnik.

5. Anwendet man die Curettagetechnik, so muss man unter Hinblick auf die Gefahr des Rezidivs und der malignen Entartung wenigstens während 3 Jahre dem Pat. folgen.



## A SURGICAL APPROACH FOR SYNOVECTOMY OF THE KNEE JOINT

BY

CARL HIRSCH, M.D.

Total synovectomy of the knee-joint is a rather rare operation. Usually only parts of the synovial membrane are removed. Excluding tumours the most important indication for partial removal of the joint capsule is chronic synovitis, usually with exudate. Diagnostic excisions are also made in order to obtain material for pathological examination.

One of the disadvantages of opening the knee-joint in irritative conditions is the necessary post-operative inactivity. If this is prolonged, the scar formation and adhesions, which so readily occur, delay the recovery of the original function of the joint.

If the operation could be performed so that the tissues most important for the function of the joint were not injured, the indications for synovectomy could be widened, and the results of therapeutic excision of the capsule could be better assessed. Some of the bad results which are now obtained may be caused by intra-articular synechiae.

In 1945 *Abbott* and *Carpenter* gave a full account of the different approaches to the knee-joint. All involve incision of the fibrous capsule in one way or another, and the period of postoperative immobilisation is determined by the time which the capsule takes to heal. Even when the fibrous capsule is carefully sutured, so that movements can be begun early, the fact that there is a lesion of the capsule means that the normal

function of the knee cannot be restored before a considerable period of time has elapsed, and the scar causes a loss of elasticity which limits the range of movement. Incision of the outer capsule has, however, the advantage that more of the joint can be seen, and this may be of diagnostic importance.

In cases in which one can a priori decide to limit the operation to a partial excision of the synovial membrane, it is often sufficient to remove only the suprapatellar pouch, which, with few exceptions, communicates with the knee-joint. In 7 cases the author has used a method which has not, as far as he can find, been described before, and which seems worth describing.

The patient lies on his back with the knee extended. A curved incision is made round the upper medial border of the patella (see fig. 1).

The fascia of the vastus medialis is found deep to the subcutaneous fat. It is incised and the muscle is divided by blunt dissection in the line of the fibres, which run roughly at right angles to the skin incision (fig. 2 and 3).

One now has direct access to the suprapatellar synovial pouch and can usually separate off its upper and medial parts by blunt dissection. Either the whole or parts of this sack-shaped extension from the joint cavity are freed and excised. The fibres of the vastus return to their original position, so the author inserts only a few separate subcutaneous and skin sutures. The vastus is not sutured. The operation has always been performed after application of an Esmarch's bandage, and no bleeding has been encountered. After the wound is closed, a compression bandage is applied to the knee, with maximum pressure over the site of the pouch. This bandage is left on for one or two days. It is then replaced by a light elastic bandage, and active exercises, consisting of raising the extended leg and flexion exercises, are now begun. After a week the patient is allowed to get up.

4 of the cases had a chronic non-specific exudative synovitis, and 3 a subacute polyarthritis. No complications occurred.

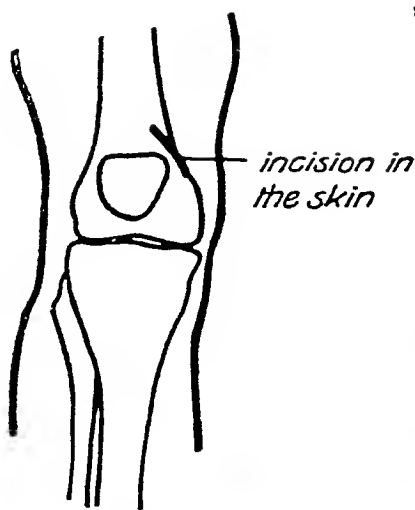


Fig. 1.

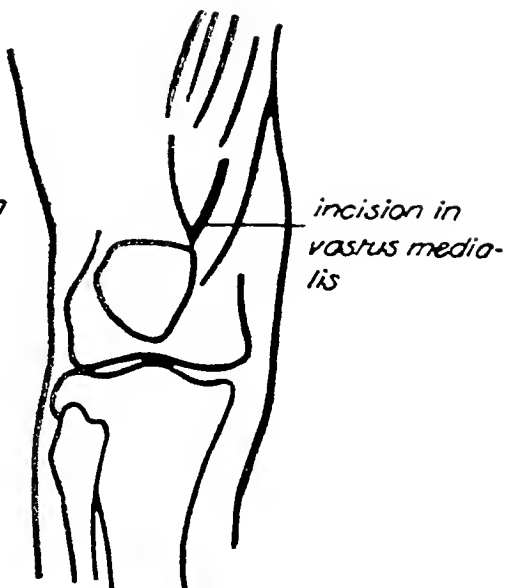


Fig. 2.

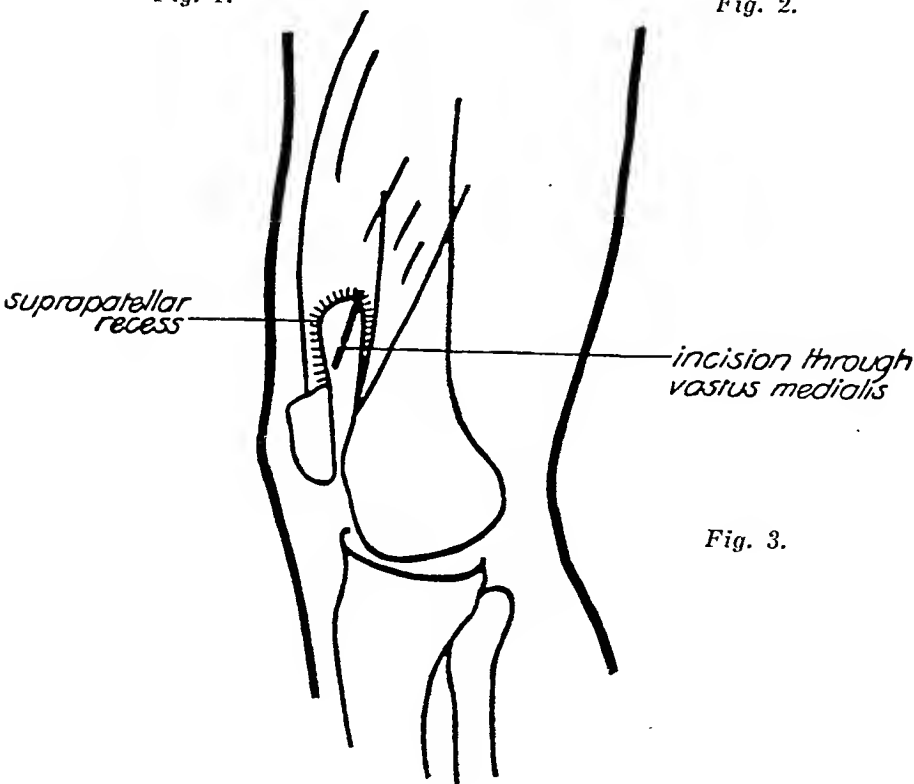


Fig. 3.

## SUMMARY

The author describes a technique for partial or total synovectomy of the suprapatellar pouch. He uses a trans-muscular approach through the vastus medialis, and the fibrous capsule is not damaged. In this way the risk of scarring and adhesion formation is reduced, and the post-operative function is less impaired because the operation allows early movements.

## RESUME

L'auteur décrit une technique de synovectomie partielle ou sub-totale de la bourse supra-partellaire. Il utilise la voie trans-muculaire à travers le vastus medialis et la capsule fibreuse n'est pas endommagée. De cette manière, on diminue le risque de cicatrice ou de formation d'adhérences, et la fonction post-opératoire est moins troublée, étant donné que l'opération permet le rétablissement rapide des mouvements.

## ZUSAMMENFASSUNG

Der Verfasser beschreibt eine Technik für die teilweise oder subtotale Synovektomie des Recessus suprapatellaris. Er verwendet einen transmuskulären Zugang durch den vastus medialis, wobei die fibröse Kapsel nicht geschädigt wird. Dadurch wird die Gefahr der postoperativen Narben und Adhäsionsbildung herabgesetzt. Die postoperative Funktion ist weniger gestört, da die Operation zeitige Bewegung erlaubt.

## LITERATURE

*Abott, L. C. and Carpenter, W. F.: Surgical Approaches to the Knee-Joint. J. Bone and Jt. Surg. Vol. XXVII, 2, 1945.*

# PROCEEDINGS OF THE NORDISK ORTOPEDISK FORENING'S 24TH MEETING IN HELSINGFORS JUNE 1949

The annual meeting of the Scandinavian orthopaedic association was held at Helsingfors, Finland June 49 under the presidency of G. Wallgren, Helsingfors.

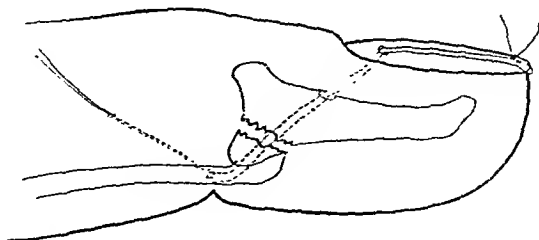
## EXPERIENCE WITH BUNNELL'S PULL-OUT WIRE SUTURES by Erik Moberg (Göteborg)

Bunnell's method of suture with stainless steel wire and a pull-out wire has been used in the reconstruction of the hand, as shown in the picture and in the Table.

The pull-out wire technique has been used for	
attachment of tendons in tenodeses .....	8 cases
attachment of digital ligaments .....	5 „
attachment of ruptured dorsal aponeurosis	
to the base of the middle phalanx.....	7 „
ditto to the base of the distal phalanx.....	16 „
attachment of flexor profundus to its fractured	
insertion .....	3 „
attachment of tendons to the skeleton .....	37 „
in free tendon transplantations	
in reattachment of tendons	
in tendon transfers	
suture of flexor tendons .....	3 „
	79 cases

In 2 cases the pull-out wire broke when pulled; this is a complication which can, no doubt, be avoided by using a rubber band for traction on the suture in cases which may give difficulty. No gliding function was obtained in the 3 cases of group 7. In the rest of the cases the results

were uniformly good, and the method can be regarded as a considerable advance in a field where other techniques are difficult to carry out and have given unsatisfactory results.



Suture and pull-out wire for fixing the fractured attachment of the flexor profundus to the finger.

#### DISCUSSION:

*Bentzon* (Århus) has for a number of years consistently used the pull-out wire principle in various operations, e.g. in the interposition treatment of painful pseudarthrosis fractures of the carpal navicular bone. In these cases the fatty connective tissue flap is fixed to the bottom of the fracture gap with a suture which is passed double through the skin on the volar surface of the wrist. For these operations he always uses fish gut (silkworm gut), which never give trouble in pulling out as they are so smooth and flexible.

*Severin, Moberg.*

#### MEDULLARY NAILS AS AN AID TO CERTAIN PLASTIC BONE OPERATIONS

by *Anders Westerborn* (Göteborg)

Medullary nailing has now won a secure place in the surgery of fractures. Experience of its use in plastic bone operation is, however, still small, and it is desirable that cases in which it has been used in this way should be reported.

In Surgical Department II of the Sahlgrenska Sjukhus, medullary nailing has been used in 20 cases of bone-shortening, bone-lengthening, correction of faulty positions and joint resections, and the experience gained has been very encouraging. The main advantages are the absolute fixation, which facilitates union, and the avoidance of a big plaster cast in the after treatment. Further, stiffness in the joints is avoided, since physiotherapy can be started early and the patient can be allowed up early. In some cases medullary nailing makes it possible to carry out a more radical treatment than would otherwise be possible. The nail has no harmful effect on the tissues, in particular none on the bone-

marrow. The risk of infection is very small, and can be still further reduced by the use of sulfa and penicillin preparations.

Some typical cases of medullary nailing for resection of the knee, bone-shortening and subtrochanteric osteotomy were reported.

#### DISCUSSION:

*Bentzon:* Dr. Westerborn's proposal to widen the indications for the use of medullary nailing must be regarded critically. The medullary nail principle can undoubtedly be said to have some mechanical advantages, but from both the biological and the general surgical points of view the method is less attractive, and one can never disregard the risk involved in inserting such a large foreign body into the marrow cavity. In October, 1948, I attended the Annual Meeting of the B.O.A. in Belfast, where a paper was given on the medullary nailing of fractures. The British orthopaedic surgeons present were completely silent; they clearly avoided the method. I, however, felt bound to report a case of pseudarthrosis of the femoral shaft which had been treated by medullary nailing, and which, in spite of all lege artis treatment (preparatory penicillin treatment, etc.), became infected. In such cases the infection spreads rapidly along the nail through the whole marrow cavity. Finally it was necessary to amputate.

I regard the use of a medullary nail for a simple knee resection, involving as it does the opening of the medullary cavities of both the tibia and the femur, as inexcusable, for there are a number of other, less extensive, and very satisfactory methods of primary fixation after a knee resection.

*Agerholm-Christensen* (Copenhagen): We have become very reserved in our use of medullary nailing. In our experience callus formation is delayed and the risk of delayed healing and possible pseudarthrosis is increased. We have also seen that the medullary nail may bend after a long period of non-weight-bearing, and we have been faced with the difficult problem of removing the bent nail, for which it is often necessary to chisel away a considerable amount of bone, and of then performing some other kind of osteosynthesis.

*Sten Friberg* (Stockholm): I should like to join myself with what Dr. Bentzon has said. It cannot be denied that the Küntscher nail is sometimes a great help, but it has hardly had the general success which was at first expected, and surgeons in various places are becoming a little more cautious about its use. Whether it is used for fresh fractures, pseudarthroses, bone shortenings, or joint resections, it has been generally found that the consolidation is slow. This could also be seen in three of Dr. Westerborn's cases. One must also question both the advisability

of performing an arthrodesis in a still active arthritis and the wisdom of using in the knee joint a Küntscher nail, which makes its own track into the medullary cavities and reduces the chances of a good contact of the osteotomy surfaces.

*Westerborn, Støren.*

## THE INDICATIONS FOR OPEN REDUCTION OF CONGENITAL DISLOCATION OF THE HIP

*E. Platou (Oslo):* The results of open reduction of 50 hips in 44 children with congenital dislocation of the hip.

The indications for open reduction were:

- 1) All hips which a skilled orthopaedic surgeon could not reduce in 30 minutes.
- 2) All hips where the head was too far out and re-dislocated easily without marked slipping.
- 3) All hips which redislocated while in plaster or later, and in which there had been no fault in technique.

The hip-joint was exposed by a Smith-Petersen's incision. In about half of the cases it was not necessary to divide the rectus muscle.

The joint capsule was opened widely with a cross-shaped incision, and the tissues preventing reduction were removed. The bony parts of the acetabulum were never touched.

Plaster was applied with the hip in full extension, 50° abduction, and 30-40° pronation, and left on for 8 weeks. After this a plaster shell was applied with 30° abduction and still 30-40° pronation. Massage and stretching was given daily. After 4-8 weeks the child was allowed up on a triecyle; after a further 4 weeks he began to walk. i.e. 4-5 months after the operation.

The obstructions preventing reduction were:

Isthmus .....	21 hips
Isthmus + ligamentum teres .....	4 hips
Ligamentum teres .....	5 hips
capsular fold above .....	3 hips
"      "      below .....	10 hips
"      "      " + ligamentum teres .....	3 hips
Connective tissue in the acetabulum .....	4 hips

In some cases the reduction was unsatisfactory. The head was too big for the acetabulum, and could not be brought properly under the upper rim. In these cases a shelf operation was considered. A shelf was made at



the end of the operation in 5 hips, and a later date in 5 hips; in 2 it was made before the open reduction.

When the head is in position, the question is: what is the position of the limb and how much pronation is required to keep it in the best position. This depends on the original antetorsion. The physiological antetorsion is about 20°, so that a corresponding pronation of the limb is normal. If 60-90° pronation was necessary a rotation osteotomy was performed 4 weeks after the reduction.

The clinical results are summarised under the following headings:

*Excellent*: no symptoms from the hip-joint.

*Good*: slight symptoms, viz: a slight limp and slight pain after extra exertion, but no inconvenience from the hip in daily life.

*Bad*: a marked limp, with constant pain and considerable inconvenience from the hip in daily life.

The radiographic results are also summarised under 3 headings:

*Cured*: a normal hip-joint (In most cases there will be some small deviations from the normal, but in this group they were thought to be insignificant).

*Good result*: a moderate deformity of the femoral head and neck or of the acetabulum, a slightly high position of the head, but no subluxation.

*Bad result*: luxation or subluxation, and marked deformity of the head and neck.

For the sake of simplicity the material is divided into 2 groups, good and excellent results being taken together.

1-5 years after operation:

	On discharge	1-5 years after operation
Clinical result .....	18 good	18 good
	6 bad	6 bad
Anatomical result .....	17 good	17 good
	7 bad	7 bad

The primary results have remained unchanged. But the picture is quite different 5-13 years after operation.

	On discharge	5-13 years after operation
Clinical result .....	20 good	13 good
	3 bad	10 bad
Anatomical result .....	19 good	6 good
	4 bad	17 bad

Out of 20 good primary clinical results, 7, or one third, and of 19 good primary anatomical results 13, or two thirds, have changed to bad results.

Of 13 clinically good results only 6 are anatomically satisfactory. This demonstrates the old experience that one cannot say anything definite about the function from the radiographic picture. But I am afraid that in 10 years time many of the 13 now classed as good clinical results will no longer be in that group.

*Rotation osteotomy* was performed 4 times, twice with a good result and twice with a bad result.

To summarise our experiences:

One should not be over reluctant to use open reduction.

Smith-Petersen's incision is the simplest approach to the hip-joint. It does not cause much bleeding, and children stand the operation well.

We are most glad that we have been able to see the importance of antetorsion for the position and have been convinced that rotation osteotomy is both useful and necessary. It should undoubtedly be used much more widely than it is.

*E. Severin* (Göteborg): Open reduction of congenital dislocation of the hip has been reserved by most surgeons for cases in which closed treatment is unsuccessful. In recent years the indications for open reduction have been widened by some surgeons. The most extreme representative of the active group was the late *Leveuf*. He considered that closed treatment of a complete dislocation was bound to fail, since the limbus, the capsule, the ligamentum teres and other soft tissues must lie as a hindrance to the head on its way into the acetabulum. *Leveuf* wrote: "When good results were obtained in congenital dislocation of the hip by closed reduction without arthrography, according to the former methods, the condition was a primary subluxation and never a true luxation." (*Jour. of Bone Jt. Surg.*, Oct. 1948). Consequently, he recommends open reduction for all cases with complete dislocation.

*Leveuf's* method of operation is drastic. After chiselling away the trochanter, the soft parts are cleared out of the acetabulum, the capsule is freed from off the ilium, a shelf is made, and in some cases an osteotomy of the neck of the femur is performed. The neck is pinned with the head and neck in the corrected position.

The most important argument in favour of this high operation should be that there is a primary interposition of soft tissues between the head and the pelvis, and that these could not be removed by closed treatment.

In order to show the progress of a congenitally dislocated hip after reduction I have studied the arthrograms of 115 dislocated hips in 77 cases treated during the years 1937-40 at the Orthopaedic Clinic, Vanförcanstan, Stockholm. In one third of the cases arthrography was repeated one or more times during treatment.

The main lessons which can be learnt from the investigation are: When a complete dislocation is reduced in a child over 1 year one can never expect that the cartilaginous roof of the acetabulum will immedi-

ately take on a normal form. In half of the cases the limbus is pushed up above the Y-line, and in the other half it is interposed between the head and the pelvis. A primary interposition does not, however, mean that closed treatment is bound to fail. On the contrary, it is a usual finding that the interposition is overcome in the course of a few weeks or a few months, if the head can be maintained against the acetabulum. The later course of these cases with primary interposition is no more unsatisfactory than that of other cases. In other words: a primary interposition does not in itself justify open reduction.

72 hips, all with complete dislocation confirmed on the arthrograms, which have been treated by closed reduction, have been followed up for at least 5 years. In no case did dislocation recur after the treatment was completed. In one third of the cases subluxation had occurred, and in the remaining two thirds the head was in a normal position in the acetabulum.

The arthrograms as well as the follow-up studies show that even complete dislocations could be successfully treated by closed reduction. Published pictures and case-histories show that deformations occur in a very high percentage of hips treated by open reduction. Closed treatment carried out by modern methods, with early gentle reduction and free rotation at the hip after reduction, gives late anatomical results which, as far as we can judge now, are far superior to those of open treatment. It would therefore be incorrect to use open reduction as a standard method in the treatment of congenital dislocation of the hip. Open reduction should only be considered for cases in which closed reduction does not give the desired result.

(Paper to be published with illustrations, in the *Acta Orthopaedica Scandinavica*.)

*S. Barner-Rasmussen (Helsingfors):* At the Orthopedic Hospital of the Rehabilitation Centre of the Invalidisassatio-Invalidstiftelsen, about 50 children with congenital dislocation of the hip have been treated by open reduction during the last 3 years. The reason for adopting this procedure was the dissatisfaction felt here—as elsewhere—with the large proportion of poor results obtained with closed reduction. The follow-up of the immediate results of the operation is still in progress, so it is not possible to give exact information.

The indications for operation have always been considered in relation to the arthrograms after closed reduction has been tried. At first these were regarded with considerable pessimism, so the indications were relatively wide. But increasing experience has narrowed the indications to:

cases in which the femoral head cannot be brought down to the level of the acetabulum,

cases which have been unsuccessfully treated in other hospitals, or have re-dislocated while in plaster,  
 cases in which the head will not pass the isthmus,  
 and finally cases in which the arthrogram shows a significant and massive inter-position of the soft parts (not contrast positive) between the head and the bottom of the acetabulum.

In border line cases unilateral involvement favours operation, and bilateral involvement is a relative contra-indication.

## TECHNICAL ASPECTS OF THE OPERATIVE REDUCTION OF CONGENITAL DISLOCATION OF THE HIP

by *F. Langenskiöld* (Helsingfors)

The technique used at the Orthopaedic Hospital of the Rehabilitation Centre of the Invalidisäätiö-Invalidstiftelsen has been influenced by the following observations:

- 1) Most of the redislocations seen after manipulation are anterior, obviously due to the marked anteversion of the head and neck, combined with external rotation.
- 2) After reduction, the gluteus minimus muscle is flaccid.
- 3) The longer the period of immobilisation after operative reduction, the poorer is the mobility.

From these observations we have drawn the following conclusions:

- 1) An anteversion of more than  $60^\circ$  must be corrected by osteotomy.
- 2) The internal rotation must not be awakened by any such measure as detaching the gluteus minimus muscle from the iliac crest. Instead, it should be strengthened by attaching the capsule to the neck, under tension, and by transplanting the greater trochanter, with the insertion of the gluteus muscles, downwards and backwards.
- 3) Immobilisation in plaster is reduced to 2-3 weeks, followed by 3 weeks of skin traction.

A detailed report of the technique will be published in this journal.

## REDUCTION AND SHELF OPERATIONS IN OVER-AGE CASES OF CONGENITAL DISLOCATION OF THE HIP

by *Gunnar Wiberg* (Lund)

Over-age cases of congenital dislocation of the hip, by which is meant cases which do not come for treatment in the first 2 years of life, may be treated by slow reduction by traction applied for several weeks. When, in this way, the head has been reduced to a central position in the acetabulum, a final open reduction, supplemented with a shelf opera-

tion, can be performed if necessary, The shelf is made, as originally recommended by Gill, by completely breaking down the whole roof of the acetabulum. 2 cases, aged 4 and 5 years respectively, were reported.

## THE SHELF OPERATION AS A SUPPLEMENTARY OPERATION FOR CONGENITAL DISLOCATION OF THE HIP

by H. S. Nissen-Lie (Oslo)

57 patients, aged between 2 and 10 years, with congenital dislocation of the hip treated by a shelf operation after closed reduction, are reported. The indication was relaxation after repeated attempts at reduction. The operations were performed 3 months to 3 years after the first reduction.

47 patients were re-examined more than 2 years after the operation. At the follow-up examination 20 were symptom-free, 23 had no pain but a slight limp, 14 had pain and considerable limp.

The radiographic result was far worse. In only 1/4 (13) was the result satisfactory; in 29 cases there was a shallow acetabulum with a subluxated head, in 15 there was a total luxation. In 20 cases the shelf had either been totally resorbed, or was so high that it was no use.

The reasons for the bad results are discussed. The main factor appears to be the reduction. If a satisfactory reduction had not been obtained, the result was usually bad. If the reduction had been satisfactory, the result was good, but it is doubtful whether the shelf played any part in the good result.

The investigation seems to show that shelf operations do not materially improve the prognosis, and that one must always aim to obtain an anatomical reduction, if necessary by open reduction.

On the other hand, shelf operations appear to have a good result in subluxation cases aged over 5 years.

## DISCUSSION:

*Støren* (Stavern): In connection with *Nissen-Lie's* paper I should like to report one case which I believe is included in his material. I report it because the operation which I performed should be tried in cases where a shelf operation fails. The shelf operation had been performed twice, presumably both times satisfactorily from the technical point of view. When the patient came to me she had a marked limp from a strongly positive Trendelenberg. She was said to have limped more since the last operation. The radiographs shows that the acetabulum is quite indefinite, only traces of a shelf remain, and the head lies outside its outer border.

I performed an operation which was described by *Colonna*: After thorough preparation by traction in internal rotation an open reduction

is performed. The capsule is incised near its acetabular attachment. A deep, wide acetabulum is chiselled out at the original site, so that one can see the Y cartilage centrally at the bottom. The capsule is sewn up over the head. No attempt at all is made to mould the head, which is reduced. Plaster is applied for 3-4 weeks in extension and abduction.

The operation is drastic, and cannot be called physiological, but *Colonna* has followed up cases for 10 years and found such good results that I thought it justifiable to try the method in a hard case like this. I operated on her 4 months ago, and the preliminary result at any rate is good. There is no danger of re-dislocation, but the mobility will probably be reduced.

*E. Severin:* In assessing the indications for open reduction, it is not possible so to simplify the problem that open reduction should be done in all cases where closed reduction has been unsuccessful. If the patient is over age, or the dislocation is very high and there is rigidity of the soft tissues, either reduction cannot be performed by any means, or it can be carried out only with such trauma to the joint that secondary deformity and stiffness must be the inevitable result. One must be clear about what will be gained and what lost by the operation. A stiff hip on one side does not necessarily mean a big disability for the patient. Two stiff hips, particularly if they are painful, are severely disabling. The indications for treatment cannot therefore be the same for cases with dislocation on one and on both sides.

In cases with unilateral dislocation one must, even when there is evident risk of later deformans changes in the joint, try to secure the femoral head in the region of the acetabulum. When, by reduction, the considerable difference in the length of the two legs is reduced, a good foundation has been laid for future orthopaedic procedures, whether these be arthroplasty or arthrodesis, if they should be necessary. Even though the joint either becomes or is made quite stiff, the price is worth paying.

This is not so in cases with bilateral dislocation. If, in these cases, bilateral painful stiff hip develops, the treatment has worsened the patient's condition instead of improving it. A persistent dislocation can sometimes give astonishingly little trouble. I have seen a patient with persistent bilateral congenital dislocation of the hip who was still, at 35 years of age, doing heavy agricultural work without any complaint except of his limp. However, subluxation with arthritis deformans usually gives considerable trouble in adults. When the reduction is very difficult the risk of future deformity and subluxation is always considerable. If the dislocation is bilateral it may be best to avoid completing the reduction. If, in a case of bilateral dislocation, one succeeds in reducing only one hip, the future functional result will

be very poor. Usually subluxation and deformans changes in the reduced hip occur early. It is true that the patient limps worse on the unreduced side, but as it is the reduced side which is painful, it is the reduced side which causes the most disability. So soon as it is seen that in a case of bilateral congenital dislocation of the hip it is only possible to reduce one hip, this hip should be redislocated and both hips left unreduced.

This negative indication will be altered the day we have a fully reliable arthroplastic treatment.

The following principles for the treatment of congenital dislocation of the hip might be laid down:

A. Closed reduction should always be attempted first. It should be carried out as early as possible and without much manual force. "Slow" reduction with extension and abduction may be tried. If reduction cannot be obtained without trauma, closed reduction is considered to have failed.

B. Open reduction is used:

I: In unilateral cases

- a) with unsuccessful primary reduction,
- b) with persistent subluxation after closed reduction, in spite of 2 months retention of the head against the acetabulum,
- c) with redislocation or a tendency to redislocation after complete closed reduction.

II: In bilateral cases

- a) Closed reduction has been successful on one side. Open reduction is performed on the other side
  - 1) with unsuccessful primary closed reduction
  - 2) with persisting interposition after bloodless reduction in spite of at least 2 months retention of the head in the acetabular fossa,
  - 3) with redislocation, or a tendency to redislocation, after complete closed reduction.
- b) Closed reduction has failed on both sides.

If the head can be pulled down on both sides, open reduction should be considered.
- c) If there is a high dislocation with rigidity of the soft tissue on both sides both joints should be left unreduced.

In these proposals I have intentionally avoided stating any definite age limits. The radiographic appearance and the findings on palpation, perhaps under anaesthesia, are more important than the patient's age.

*Bentzon, F. Langenskiöld, Berntsen, Friberg, Platon.*

## METATARSUS PRIMUS FLEXUS

by K. Vainio (Helsinki)

By the term metatarsus primus flexus we mean the plantarflexion of the 1st metatarsal, which occurs when the peroneus longus is stronger than its antagonist, the tibialis anterior. In this condition the ground is touched first, when walking, by the fallen capitulum, and secondary changes develop on it. Metatarsus primus flexus may be seen in a wide variety of static and functional disorders of the foot. It was seen in 45 out of 1500 patients at the Orthopedic Hospital of the Rehabilitation Center of Invalidisäätiö-Invalidistiftelsen.

*Treatment:* For mild cases, conservative treatment with exercises and foot support. For moderately severe static deformities, *Bentzon's* operation, i.e. division of the peroneus longus tendon and attachment of the proximal stump to the peroneus brevis. For paralytic cases, the peroneus longus should be transferred to the insertion of the tibialis anterior. *Gocht's* transplantation of the extensor hallucis longus to the first metatarsal does not give a satisfactory result. For severe cases with fixed deformity, the tendon transplantation is supplemented by subtalar arthrodesis or wedge resection in the cuneometatarsal joint. In spastic cases the peroneus longus is weakened by *Stoffel's* technique.

## A CASE OF ACQUIRED LUMBAR SPONDYLOLISTHESIS

by Lars Unander-Scharin (Stockholm)

A case of spondylolysis and spondylolisthesis of the neural arch of a 3rd. lumbar vertebra, which had shown no abnormality at 3 previous radiographic examinations, is reported. The spondylolysis was observed 5 years after an osteosynthesis between the 3rd. lumbar vertebra and the sacrum. The osteosynthesis had been performed because of pain in the back, associated with definite radiographic evidence of degeneration of the 4th. intervertebral disc. A theoretical distinction has been made between congenital, acquired and traumatic spondylolyses. Previously, only congenital spondylolyses had been demonstrated. This case can be regarded as confirmation of the occurrence of acquired spondylolysis. It is also interesting as being the only one reported as occurring after a lumbar osteosynthesis.

## DISCUSSION:

*Bentzon* reported that the Orthopaedic Hospital in Århus had had about 100 cases of spondylolisthesis. In only 1 of them was it possible to show on radiographs taken at definite intervals any increase in the displacement. He described and showed on a film the method he used for fixing the spondylolisthesis with a long cross graft, inserted into a notch in the lower surface of the spinous process of the vertebra above the spondylolisthetic vertebra—i.e. usually L IV—so that it rests, on both



sides, on the gutters chiselled out on the iliac crest (see *Aeta Orthopaedica Scandinavica* Vol. IX P. 175).

*Støren:* Regarding the operative treatment of these cases I should like to mention the operation which is rational for cases with considerable slipping at the spondylolisthesis, i.e. fixation of the bodies with an anterior hone graft.

We know *Pawel's* law for fracture of the femoral neck: that compression encourages and tension discourages union at a pseudarthrosis. Examination of a spondylolisthesis with a considerable degree of slipping will show that the slipping will tend to compress an anterior graft and to pull on a posterior graft. The operation in advanced cases of spondylolisthesis is not so simple as *Mercer's* description in his *Orthopaedic Surgery* suggest, and *Mercer's* technique cannot be used in these cases. I have chiselled out a groove a finger's breadth wide and 2-3 cm deep in the spongiosa of LV and S1, cut out as much as possible of the intervertebral cartilage, and replaced it with spongiosa from the vertebral bodies: finally, a spongy graft of iliac crest is fixed sagittally into the groove. I have done this operation 5 times, first in 1944. The complication has been a tendency to ileus after the operation; this I believe to be due to oedema of the mesentery.

*Friberg, Unander-Sharin, Nissen-Lie.*

## TRACTION LESIONS OF THE PERIPHERAL NERVES

by *Agerholm-Christensen* (Copenhagen)

Apart from birth lesions the number of cases of traction lesions of the peripheral nerves is rather few, and these lesions undoubtedly occur more often than they are recognised. (Short histories of 5 typical cases seen in the last few months were given here).

When I was working with Professor Seddon at the Peripheral Nerve Injury Unit at the Wingfield Hospital, Oxford in 1944-5, I collected together 94 cases of traction lesions of the peripheral nerves and we were to have published a paper on them.

The subject is a big one and rather complicated, and only a few points will be made here.

The 94 cases formed about 7 % of the first 1300 nerve lesions seen at the Centre.

*Causes:* The material was collected during the war, but the accidents which caused the lesions can all occur in peace time. 47 were caused by road accidents (31 motor cycle, 20 car, 6 bicycle), 16 by flying accidents, 7 by falls, 4 by machinery accidents and 3 by surgery.

*Age-groups:* 49 patients were aged between 20 and 30 years, and 21 between 30 and 40.

*Nerves Involved:* The brachial plexus and its nerves were affected

in 67 cases, most due to characteristic falls on the shoulder. The sciatic nerve was affected by 13, either by dislocation of the hip or by hyperflexion of the extended leg at the hip. The peroneal nerve was affected in 14 by adduction of the knee, usually with evulsion of the biceps tendon.

*Morbid anatomy:* In the mildest cases, with clinical transient block,—"neurapraxia"—no changes were seen. In the severest cases there was complete rupture of the nerve with wide separation of the ends and very large neuromata. In the intermediate cases the picture showed a wide range of variation, but typical was the scattered patchiness of the changes along the nerve over considerable distances. This patchiness affected not only the nerve as a whole, but also the individual fibre, which might be injured in several places; further in some places the injury might involve the whole fibre—"neurotmesis"—while in others only the axon might be damaged, the sheaths being intact—"axonotmesis". Macroscopically it is easy to recognise a traction lesion: the nerve has often a pinkish-yellow colour its consistency is harder than normal and uneven over long distances, and its surface is irregular.

The *clinical picture* varies, of course, with the anatomical lesion. The mildest cases, with "apraxia" or "transient block" are hardly ever seen in special departments, as they recover before they arrive. The severest cases have complete motor and sensory loss. Intermediate cases show very different pictures, in accordance with the many variations of damage to the nerve fibres. On admission to a special department the clinical picture is often clearer than immediately after the injury, as there has usually been a lapse of 2-3 months and the transient block part of the picture has disappeared.

Many cases show a characteristic dissociated lesion, the motor loss being usually more severe than the sensory: e.g. there may be a complete motor paralysis of the muscles supplied by the sciatic nerve, without any sensory impairment, or a complete motor paralysis of the muscles supplied by the brachial plexus and a partial sensory loss confined to the area supplied by the 5th and 6th cervical roots.

*Progress.* Re-innervation is best followed by observing the return of voluntary muscle power. In traction lesions it does not follow the course observed for nerves damaged by more direct, localised injuries, neither as regards the rate of recovery nor its progress proximally-distally. Similarly, the onset and completion of recovery, both motor and sensory, is less predictable, and one must realise that re-innervation may occur very late, e.g. more than 3 years after injury, even for the proximal muscles of the arm.

*Treatment.* The mildest cases, which show no reaction of degeneration in the muscles, recover spontaneously after a few weeks, and require no treatment beyond splinting and physiotherapy to maintain

full mobility. In the severest cases, early exploration, to discover whether there is a complete tear, is justified. If there is a complete tear the prognosis is bad, as the damage is usually so extensive that resection and suture are impossible. A cable nerve graft may, however, be considered. If there is no tear, or the lesion does not warrant exploration because of its diffuse clinical picture, treatment must be conservative and persistent. Electrical treatment of the muscles, passive movements of the joints, and splinting to avoid over-stretching of the muscles and contractures, must be persisted with for a considerably longer time than with other types of nerve lesions, before hope of recovery is abandoned.

#### DISCUSSION:

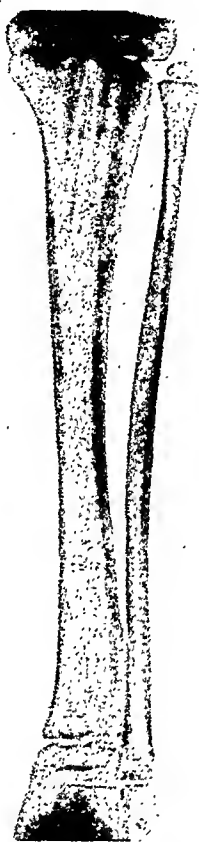
*Bentzon:* Many years ago, when working on obstetric paralyses of the brachial plexus, I was able to examine serial sections of these damaged plexuses, and found, like *Agerholm-Christensen*, that the lesions were widely scattered in the plexus. We have had similar experiences in the Orthopaedic Hospital in Århus, where explorative operations have been made on severely damaged brachial plexuses. Usually, the conditions are such that there is no possibility of operative repair of the lesion. I will take this opportunity to call attention to the quite typical, but less well-known, traction lesion, which only damages the suprascapular nerve. Usually it is quite painless, passive movements of the shoulder are completely free, but abduction and elevation of the arm is impaired by the paralysis of the supraspinatus muscle. A case which had been branded by the insurance doctor as a malingerer, because the doctor himself was ignorant of this isolated traction paralysis, is reported.

#### OLLIERS'S DISEASE

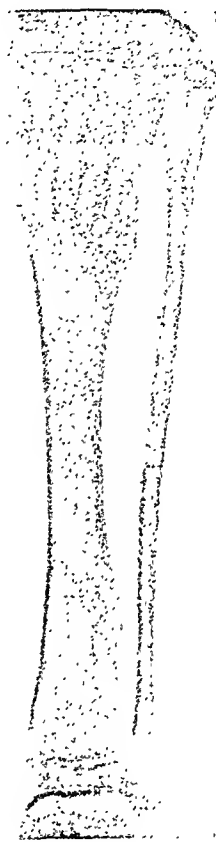
by *Bentzon* (Århus)

That form of endochondromatosis which has been called *Ollier's* disease is a rare condition. Most publications about it appear because the author has come across a single case; this he reports, together with a bibliographical survey and his own ideas on the nature of the condition—its etiology and pathogenesis. These ideas will almost inevitably be influenced in some degree by the peculiarities of the author's "own" case. At any rate, this was so when in 1924 I published my case, which was (to my mind at least) a very satisfactory one, because the condition was both sufficiently marked for the characteristic signs to be well developed, and yet not so severe that the changes on the radiographs had anywhere become so extreme that the original, very characteristic morphology was obscured. The extent and the position of the chondromatous formations in the bones involved could be clearly seen. As it is

almost exactly 25 years since I published the case (in *Acta Radiologica* vol. 3), I must assume that at least my younger colleagues here, who have not "specialized" in Ollier's disease, will not have read the article in question. I propose therefore to give a short summary of the case and to show some of the radiographs. The patient was sent to Slomann's

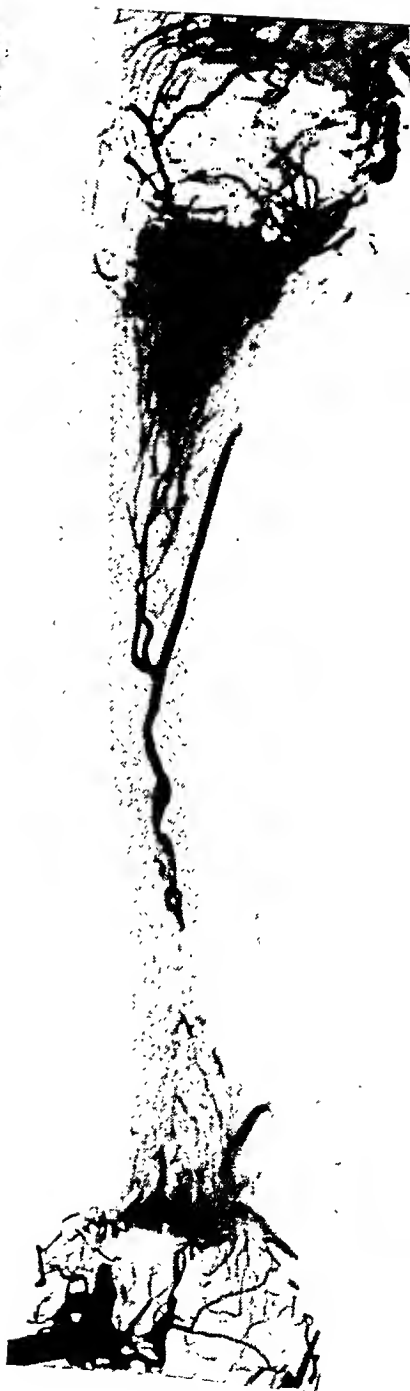


*Fig. 1a.*



*Fig. 1b.*

and my private clinic in January 1922. She was then 15 years old. Her family was a healthy one, and no other congenital deformities were known. The pregnancy and birth had been normal. When she was 5 years old, her parents (a wealthy miller family from a Danish provincial town) noticed that her right leg was somewhat shorter than the left one, but not until she was 7 was the first radiograph taken. She later, at some years' interval, twice fractured the medial epicondyle of the humerus—both times after sufficient trauma; but at 13 she fractured the lower half of the femur of the short right leg. This fracture, occasioned by a simple fall with her bicycle, hit an area affected by

*Fig. 2.**Fig. 3.**Fig. 4.*

the chondromatosis, and it is reasonable to regard it as a spontaneous fracture of that area. The fracture healed without any dislocation. When I first saw her she was a normally developed girl of 15, with normal build apart from a shortening of 7 or 8 cm. of the right lower limb. Even at the age of 7 radiography of the pelvis and lower limbs had shown rarefactions, which were streaky in the os ilium femur and tibia. If you look particularly at the changes in the tibia (at the age of 7), you will notice partly the shortening of the bone compared with the sound side, partly the presence of translucences in the tibial diaphyses and metaphyses; in the lower metaphyses these appear as somewhat irregular patches; but in the upper metaphysis they form beautiful stripes arranged in a fan, opening rather laterally and upwards (Fig. 1 a).

I have here contrasted my case with the one published by the Norwegian pediatrician *Johannessen* (Fig. 1b), and you will notice that his case was rather more severe than mine in degree, but otherwise there is a remarkable similarity between the two cases in regard to the position, and even the number of chondromatous spots and stripes in the tibia. At that time, radiography was more casual than nowadays, and people were perhaps more stingy with photographic material. At any rate, I was the first to think of taking a picture *in profile* of such an Ollier-tibia. I took it because I thought it significant that the stripes of cartilage had always just that arrangement. The profile exposure gave the interesting result you see on fig. 2 it is quite clear that the stripes follow the same course as the arteria nutritia and its larger branches in the tibia. I wrote to Mr. *Johannessen* asking him to take a profile view of his case, and it showed exactly the same thing. If you compare these photos with injection-preparations of the tibia (I have here contrasted my patient's tibia with an injection-photo of a tibia from the same age class (fig. 3), and also from a foetus (fig. 4) it can be seen quite clearly that the changes—the streaky, enchondromatous formation—in Ollier's disease are primarily an affection of the diaphysis. The part you see on the foetal preparation in fig. 4, and which shows exactly the same characteristic course of the arteria nutritia as on the preparations from the 7-year old, has nothing to do with the part of the diaphysis originating from the epiphysis, it is a piece of the ossified, primordial cartilage of the diaphysis which is shown here. The arteria nutritia enters the tibia rather high up, and runs with a markedly downward direction through the posterior cortical wall to reach the marrow cavity, where it splits up into branches running up and down the shaft. This course is reflected very clearly in the position of the chondromatous stripes in Ollier's disease. You will notice a distinct thickening corresponding to the entrance of the artery, and a marked upward translucency beginning near the posterior cortical wall rather

more distally, and obviously corresponding to the ascending branch of the nutrient artery.

We need not explain in detail that these changes, both with regard to their position in the bone and their special course, cannot have anything whatever to do with bone originating in epiphyseal deposits during the growth in length.

Other attempts which I have made to clear up the problematic etiology and pathogenesis of *Ollier's* disease (experiments with animals etc.) will be found in my original account in *Acta Radiologica* vol. 3.

My reason for stressing the above on this occasion, and in this place, is, of course, that I must disagree with most of what Anders Langenskiöld has written about *Ollier's* disease, which he regards as a disturbance of the epiphyseal growth (as *Ollier* himself and several other earlier authors also did).

A few further features are still to be added: Marked disturbances in the epiphysis e.g. Calve-Perthes' disease and *Kohler II*, do not impair, or at any rate only to very slight degree, the growth in length of the diaphysis. What makes *Ollier's* disease particularly interesting to my mind is that it is a condition in which the ossification process of the diaphysis is disturbed, and in this connection it must be pointed out that the deposition of bone, which is responsible for the greater part of the growth in length of our long bones, and which takes place juxtaepiphyseally, is in reality a diaphyseal process. By that I mean particularly that it is the diaphyseal arteries which nourish this longitudinal growth. Therefore it is comprehensible that a disturbance in the diaphysis, such as that found in *Ollier's* disease, is particularly likely to cause a considerable shortening of the diaphysis concerned.

#### DISCUSSION:

*A. Langenskiöld, Bentzon.*

#### EXPERIENCES WITH A BONE BANK

by *L. Hult* (Stockholm)

The theoretical and practical requirements of a bone bank were discussed. Bone can be kept sterile at  $\div 15^{\circ}\text{C}$  for practically as long as one likes. At the Orthopaedic Clinic of the Karolinska Institute bone from the bone bank, taken from 75 different donors, has been used for 48 operations, with good results in all cases. The use of stored bone means that in many cases there is a considerable reduction in the severity of the operation, and it is recommended for this reason. (To be published later in *Acta Orthopaedica*.)

#### DISCUSSION:

*Severin, Agerholm-Christensen, Friberg, F. Langenskiöld, Hult.*

*Storen*: I have had an experience which supports Prof. Langenskiöld's opinion that homo transplants tend to be resorbed.

In 1944 I showed to the Oslo Surgical Society a girl, then aged 4 years, who had a congenital pseudarthrosis of the tibia, with a considerable gap between the bone ends; this gap was further increased when I had had to resect the ends in order to reach an open medullary cavity. As not enough bone could be obtained from the child herself the mother was laid on one operating table and the child on another. Two full-thickness grafts, were taken from the mother and inserted in the child, so that they were in wide contact with the open medullary cavities of the two tibial ends and formed a gutter. The space was filled with tightly packed bone chips taken from the child's own healthy tibial metaphysis.

It looked fine—but gradually the mother's tibial grafts were "eaten away". We could follow the process on the radiographs. Finally, there were only two thin irregular shadows, and these did not form useful bone. I have repeated the operation now that the child is 7 years old, but I do not believe that the result will be any better this time.

#### DEMONSTRATION OF A BILATERAL KRUKENBERG AMPUTEE EARNING HIS LIVING AS A DRIVER

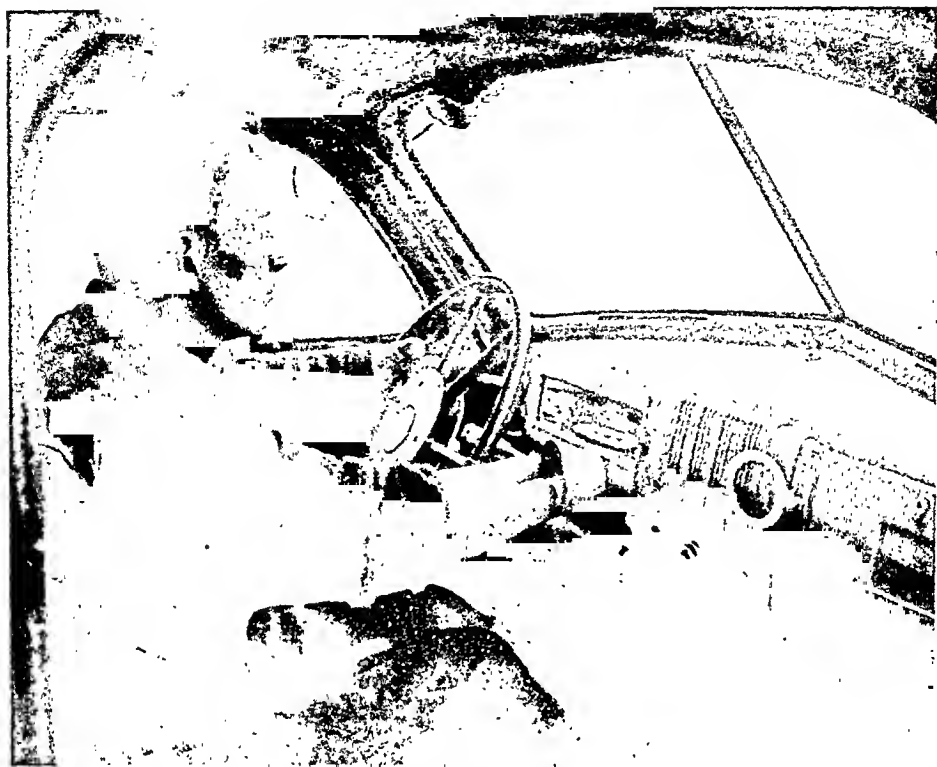
by *K. E. Kallio* (Helsinki)

As will perhaps be remembered, I showed at our meeting in Stockholm in 1947 a film of the results in cases in which I had done *Krukenberg* operations (*Acta Chir. Scand.* 1948:97:165). I will not therefore discuss the subject further, but will only demonstrate a particular case.

The patient is a man aged 29 years. He was wounded on 29.6.45 by a German land mine in North Finland, and both forearms had to be amputated immediately: in addition, there was an injury of the left leg. On admission to our orthopaedic hospital he was already in a state of deep psychical depression, which persisted for as long as he was helpless, without hands. The following spring, both the leg and his general condition had improved enough for me to be able to perform a *Krukenberg* operation on the R. side on 19 Feb., and on the L. side on 22 April. As the stumps were short it was possible to cover the two branches with their own skin, and this considerably shortened the duration of treatment. Training of the hands was rapid, and his depression disappeared as soon as he could wash himself, shave, dress and undress, etc. He was discharged on 1.7.46.

During his convalescence he occupied himself with interior decorating, weaving, cycling and rowing. As he was an iron founder by trade he had to learn a new occupation. He decided to trade. For a beginning, he transported his goods himself, on a sledge in the winter, and on a barrow in the summer. When his business improved, he bought a



*Fig. 1.**Fig. 2.**Fig. 3.*

horse, and taught himself to harness it and look after it without help. In the autumn of 1948 he came to me because he had bought a car for his work. First, he thought of employing a driver, but as he could take the engine apart and put it together again, he had boldly decided to fit the car with modifications so that he could drive it himself. His plans for these modifications were already prepared, and he wanted our orthopaedic workshop to carry them out. He was, however, afraid that the police authorities would not give a driving licence to a man without hands, unless his surgeon could convince them that the Krukenberg hands were fit for driving a car. He was given the certificate and, never having driven a car before, he went to a driving school and obtained his driving licence. Since then he has already driven 15,000 km. all over the country alone, earning his living by trading in cloth.

I will now ask my colleagues to come outside to see this man driving his car. You will see that the stumps are indeed short; the left one is 15 cm. the right 16 cm. long, and that the branches are therefore not longer than 6 and 7 cm. respectively. The branches move directly against each other and, as you can feel, his grip is strong. The sensation is good; the rate of movement is about 100 a minute. He has never used his prostheses, as they would make it impossible for him to carry on his trade. The car is a Chevrolet, and the special modifications can be seen: the choke, the hand gas, the gear, the lights, and the wheel with extra spokes (See pictures 1, 2 and 3). Now we can see how he starts the engine, uses the gear, releases the hand brake, starts the car and shows his driving abilities.

The result emphasises the Anglo-Saxon conception of *rehabilitation* or, in this special case, the importance of an arrangement whereby the same surgeon from the very beginning of the treatment has an intimate personal contact with his patient, performs all the reconstructive operations, supervises his training, and does not regard his work as finished when the patient leaves the hospital, but only when he is completely established in the employment most suitable for him.

#### DISCUSSION:

*Bentzon:* Kallio's achievements in this patient are impressive, and it is particularly interesting to hear an account of the "psychological-social" side of the problem, which has been as important for the unique result as the brilliant plastic surgery which he used for the Krukenberg operation. I should like to take the opportunity to thank Kallio officially for his help with a similar case of bilateral forearm amputation, in which he did a Krukenberg operation for us at Århus. The patient, a young mechanic, was at that time, before the operation, well on the way to becoming "demoralised" by his absolute idleness. Now he has an excellent position as telephone operator and messenger-foreman for

the Århus telephone company, writes excellently with his Krukenberg stump, and fulfills all his duties.

In my opinion the Krukenberg operation is indicated in patients who have lost both hands. We have, however, fortunately, so few of this kind of patient in Denmark that we can with difficulty get sufficient experience of its use. I personally would prefer to send all these patients to *Kallio* for their operation.

### ARTHROSIS ACROMIO-HUMERALIS

by *Agerholm-Christensen* (Copenhagen)

This term is suggested as the name of a group of painful shoulders, which appear to show a common clinical and anatomical picture.

The patient complains of pain and clicking when the arm is brought into maximal abduction and flexion. The top of the head of the humerus is tender anteriorly. Radiography shows a defect of the head of the humerus at the edge of the cartilage at this point. At arthrotomy is found a defect in the compacta and cartilage anterior to the supraspinatus tendon where the head of the humerus abuts against the acromion when the arm is in maximum abduction with flexion. Partial resection of the acromion is suggested as treatment.

### DISCUSSION:

*Wiberg, Bentzon, Agerholm-Christensen.*

### AGREEMENT BETWEEN CLINICAL SIGNS, ABRODIL MYELOGRAPHY AND THE OPERATION FINDINGS IN 350 CASES OF PROLAPSED LUMBAR DISC

by *L. Hult* (Stockholm)

In 95 % of cases with positive abrodil myelography findings, there were also positive operation findings at the level indicated, even when there were no clinical signs from that level. A negative abrodil myelogram does not exclude a disc prolapse, especially if there are marked clinical signs. In 11 cases which were operated on in spite of negative myelography, and in which there were no clinical signs of the level of the lesion, no prolapse could be found in any case. The investigation showed that abrodil myelography is a valuable aid in the diagnosis of ruptured disc.

### DISCUSSION:

*Gunnar Wiberg* (Lund): The value of myelography in the diagnosis of ruptured disc has been discussed, and I have myself maintained that in the majority of cases one can diagnose a root compression by a careful clinical examination. At the time when I began to operate

without preliminary myelography, complications became more frequent than they are nowadays; but in spite of this I still believe that it is unnecessary to use the method routinely. Undoubtedly, myelography has its use in doubtful cases, but by itself it is by no means 100 % certain, particularly in cases with lumbosacral prolapses, in which the anatomy of the dural canal is known to allow a prolapse to be present without its being necessarily shown on the myelogram.

*A. Langenskiöld, Friberg, Hult.*

ON SUBTROCHANTERIC OSTEOTOMY FOR WEAKNESS OF ABDUCTION OF THE HIP AFTER INFANTILE PARALYSIS  
by *E. Lehtovaara* (Helsinki)

Paresis of abduction of the hip after infantile paralysis causes much the same impairment of function as congenital dislocation of the hip. The main disability consist in the marked tilting toward the affected side, when weight is put on the paralyzed leg, and a strongly positive Duchenne-Trendelenburg sign. For the correction of this deformity we have at the Orthopedic Hospital of the Rehabilitation Center of the Invalidisäätiö—Invalidestiftelsen used the subtrochanteric osteotomy of *Shanz*, particularly because this operation has in our hands given good results in correcting congenital dislocation of the hip.

The technique has been mainly the same as that of *Schanz*, except that the osteotomy is made in a particular way, with angleshaped fracture surfaces. Immobilization in plaster is maintained for 8 weeks. The average duration of treatment has been 3 months. 21 cases have been treated in this way, of which 18 have been followed up. The results of the treatment were good or satisfactory in 18 cases on discharge, and in 13 cases at the follow-up examination. 3 of the cases with bad final results had already been acknowledged as failures before discharge. The failures were due to straightening of the osteotomy angle because of unsatisfactory immobilization. For this reason, fixation of the osteotomy fragment with a metal plate and screws being tried.

In all cases with a satisfactory result it was found that the stability of the hip had improved, and with it the ability to walk. The tilting of the upper part of the trunk was reduced, and in some cases nearly eliminated. In most cases Duchenne-Trendelenburg's sign had become negative. There was no disabling reduction of mobility nor any pain in the hip.

DISCUSSION:

*Berntsen, Wallgren, Wiberg, F. Langenskiöld, Lehtovaara.*

## MORTON'S DISEASE

by *N. Ringertz* and *L. Unander-Scharin* (Stockholm) see p. 327.

## DISCUSSION:

*Bentzon* suggested that the condition is clinically characteristic, but in its pure form is not very common. It is the occurrence of attacks of severe pain localised to a single metatarso-phalangeal joint which are the main symptom. In refractory cases he has done a simple but quite extensive resection of the metatarsal head. It is a minor operation, which can be done through a small dorsal incision, and has always been effective. In no case has there been any trouble from the loss of one of the three middle (II, III, IV) metatarsal heads.

*K. E. Kallio*: A few weeks ago a patient came to me with Morton's disease. He had already been ordered foot supports, but the pain had got steadily worse and persisted day and night. I removed the interdigital nerve between the 3rd and 4th metatarsals and found the neuroma, which I now have in a bottle. The patient lost his pain immediately and the lateral side of the foot, which had become insensitive, recovered its sensation.

*Lindström, F. Langenskiöld, Severin, Agerholm-Christensen, Friberg, Ellonen.*

## THE TREATMENT OF CONGENITAL CLUB-FOOT IN CHILDREN, AND ITS LATE RESULTS

by *Støren* (Stavern)

The various reports of late results of the treatment of club-foot all suffer from different weaknesses. The most common failing is that the follow-up period is too short. In club-foot particularly it is right to say "do not judge the day until the sun has gone down".

I have personally treated and followed up 104 children with, in all, 177 club-feet. These are classified according to the original degree of deformity and the degree of fixation into mild, moderate and severe.

A curve shows that the majority, 64, had a severe degree, 30 a moderate degree and 10 a mild degree of club-foot. The relapse rate is seen to be, as would be expected, greatest among the primarily worst cases: i.e. 97 %, with 66.7 % among the moderate cases, and 30 % among the mild. The greatest number of relapses occurred at 7-8 years of age.

The high figure for the relapse rate is due to the high standard required for a good result. All cases with a tendency to relapse are counted as relapses—but if in these cases the right treatment is applied in good time, the results are very good. (Resistant relapse cases which later developed normal feet were shown on a film).

2 cases, which, after 6 months treatment from 2 weeks old developed normal feet without any tendency to relapse—without any after treatment—are excluded. These cases are assumed to have had another aetiology than the normal club-foot. They may be examples of the old theory of abnormal position and pressure in utero. The tendency to relapse is quite different in common club-foot, and has certainly a quite different fundamental cause.

Club-foot in arthrygryphosis multiplex is usually of a different type from the usual club-foot—it represents congenital defects of the muscles and joints of the feet as found in the other joints.

Another weakness of the different follow-up investigations is the different evaluation of the results. What one calls a good result, another calls a bad result.

(A picture from J. Bone Joint Surgery, October, 1947, was shown). This is described as “an excellent result 3 years after treatment”.

I call it a less good result, showing incipient relapse. As comparison I should like to show one of my own cases, which, 5 years after treatment, looks considerably better, but which, I consider, shows incipient relapse of one foot.

I will also show how photographs by themselves can lie. The foot's position in walking must be shown—either on a film or in real life. The result can be assessed only from a film or from the patient.

Radiographs are also necessary; they must be taken not only from above, to show the talo-calcaneo angle and the foot axis, but also from the side, with the foot in maximum dorsiflexion. In this way rocker-foot will be found where least expected, since in feet with apparently good dorsiflexion a good part of the dorsiflexion actually occurs in *Chopart's* joint. (Photographs and radiographs).

Radiographs taken from the side in this way, ought especially to be claimed of those who think that elongation of the tendo Achilles can be avoided by their treatment, for instance treatment with Dennis Browne's splint and its varied modifications.

It is the general experience that it is difficult to obtain satisfactory dorsiflexion of the foot, although one lengthens the Achilles tendon at an early stage in the treatment. Posterior capsulotomy, lengthening of the other plantar flexors, and traction on the heel with different apparatuses, helps a little. From this I conclude that the anterior part of the trochlea of the talus becomes too wide for the mortise at an very early age. Therefore, I lengthen the Achilles tendon at an early stage, as early as 6 months in cases where the radiographs show rocker-foot. This is not necessary, however, in cases where the arch of the foot shows such marked excavation that there is no risk of failure in *Chopart's* joint when the foot is forced into dorsiflexion. I always over-correct. I have never seen over-correction persist in the valgus plane, but I have

seen some relapses of over-correction in the equinovarus. I distinguish from pes plano valgus, a "pes planovalgus spuria", which clinically resembles pes plano valgus, but has a small talo-calcaneus angle. Pes plano valgus spuria is often associated with rocker-foot (Photos and radiographs).

I disagree with the old orthopaedic principle that weight-bearing in the correct or over-corrected position *prevents* relapse, and think that I have demonstrated this satisfactorily in these follow-up investigations. I do not deny that weight-bearing in the correct position is of some importance in preventing relapse but I believe that this is over-estimated. In contrast to what has been said by C. G. Thomasen, a big angle between the talus and the calcaneus is no guarantee against relapse. I will demonstrate this with radiographs and photos. The author's method of treatment has been to obtain the greatest abduction possible and put the foot in plaster, as early as possible, preferably the day after birth. The plaster is changed with further correction a few days later. Over-correction is seldom obtained later than after 2 weeks. I follow the well-founded reduction principles described by Thomasen in 1940, but I use other holds for the manipulation. I find his holds are more difficult, and that with them I cannot correct the more severe degrees of adduction and inflexion contracture, which is many times greater than the normal maximum supination, even though this position is the anatomical starting-point. Demonstration of holds with photos, and after that moving pictures of cases of severe club-foot treated from 2-30 days after birth, now 9 years old. The feet and gait appear normal and have a normal range of movement. When there was a tendency to relapse several years ago, treatment was begun in time.

A bilateral case with a tendency to relapse on one side, only visible when walking: here I shall interfere, and the result will be, as in the others, a normal well-developed foot.

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